Compliments of

John B. Smith

REPORT

OF THE

New Jersey State Agricultural Experiment Station

UPON THE

MOSQUITOES

Occurring within the State, their Habits, Life History, &c.

PREPARED BY

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Pursuant to the Provisions of Chapter 98 of the Laws of 1902.

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TABLE OF CONTENTS.

PART I.

Mosquito Characteristics and Habits.

CHAPTER I.

INTRODUCTORY AND EXPLANATORY.

During the session of 1902 the Legislature of the State of New Jersey passed an act, which is now Chapter 98 of the laws of that year, providing for an investigation of the mosquito problem, and the writer, as Entomologist to the Experiment Station, was intrusted with the duty of making it.

The law is as follows:

AN ACT to provide for an investigation and report by the New Jersey agricultural experiment station, upon the mosquito problem, in its relation to the sanitary, agricultural and other interests of the State.

BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey:*

1. The New Jersey agricultural experiment station be and the same is hereby empowered and directed to investigate and report upon the mosquitoes occurring within the state, their habits, life history, breeding places, relation to malarial and other diseases, the injury caused by them to the agricultural, sanitary and other interests of the state, their natural enemies, and the best methods of lessening, controlling or otherwise diminishing the numbers, injury or detrimental effect upon the agricultural, sanitary and other interests of the state.

2. The sum of ten thousand dollars is hereby appropriated to the New Jersey agricultural experiment station to be applied to and expended for the purpose mentioned in section one of this act; such expenditures to be made and accounted for in the same manner as are the other moneys appropriated to said station.

3. This act shall take effect immediately.

Approved April 3, 1902.

When I began my investigation under the law above cited, very little was known of the mosquitoes inhabiting the State, and that little was not to their credit. There was no such thing as a systematic collection and, except for the list in my Catalogue of the Insects of New Jersey, there was no recorded knowledge as to the number of species to be dealt with. No one was even certain of the names of the species collected, and everything was in chaotic state.

Dr. L. O. Howard had just published his little book on mosquitoes and that was the only tangible starting point, presenting as it did, in popular form, the status of our knowledge at that time, not only as to classification, but also as to life history and the known methods of control. It is interesting to compare that book published in 1901 with our present knowledge, and there is no better proof of its value and timeliness than the fact that all over the country it practically started the work which revolutionized our knowledge of mosquitoes in general. Few of our American species had been bred up to that time; the differences between the larvæ were but vaguely known and, in a general way, all species were supposed to have about the same habits and methods of development.

I felt convinced, from the preliminary studies that I had made, that some at least of our beliefs were erroneous, and when, at last, I was in position to carry on the investigation, I planned, first, to find what species were troublesome; second, to work out the life cycle of at least the pestiferous forms, and, third, to determine what practical methods could be adopted on a scale sufficient to deal with a State problem. I realized that until I had all the facts involved in the first and second points thoroughly established, I could not hope to cover the third satisfactorily.

This is perhaps the best place to acknowledge the assistance received from Dr. Howard and his aide, Mr. D. W. Coquillett. Dr. Howard was good enough to reply to all my questions concerning the progress of his work and to give what information I asked from time to time; while Mr. Coquillett determined for me all the species sent to him as the investigation progressed. Mr. Coquillett has the widest knowledge of American mosquitoes and his help has been invaluable. On the other hand, New Jersey supplied the material in whole or in part for no less than seven species described by him as new, so there has been at least some return for favors received.

The whole work had not progressed very far before two points came out very clearly—there were more kinds of mosquitoes than we had believed, and there were only a few that could be accounted as really troublesome. In fact, every day's field work

forced the conclusion that the State was dominated by three species and that two of these spread from limited breeding areas.

It was found that because a species of mosquito was very numerous at a given point, it did not follow that it bred anywhere in the vicinity. During 1902 *sollicitans* was the dominant mosquito at New Brunswick. My garden was full of them, and there was no remaining among the shrubs and bushes when the sun began to sink. Nevertheless I could get no larvæ of the species. I prepared pails in all sorts of ways and even added sea-salt to some of the water to induce oviposition; but all that I succeeded in getting were *pipiens, restuans* and *Anopheles*; never once a *sollicitans*. Nor was I more successful in my search elsewhere. Full of the conviction that mosquitoes must breed near where they were found, I hunted every pool near by and along the shores of the Raritan river. I found several species besides those already enumerated, but never a *sollicitans*; and this of course raised the question, where do they come from? That anything like a real migration occurred was not then believed; but it started the investigation that demonstrated it.

Before the season of 1902 was at an end I felt certain that while the old teaching that mosquitoes do not fly far from the point where they breed was applicable to a few species, others were capable of extended migrations. I felt sure of this point concerning *sollicitans* in 1902, but in 1903 I found that another species must be added to the list—one that had been confused with another and was not recognized as distinct until we bred it on the marshes and followed it inland. Mr. Coquillett named it *Culex cantator*. The summer of 1903 and the early part of 1904 were largely devoted to locating the breeding places of these migratory forms and to watching their gradual dispersion into the surrounding country. It was conclusively proved that the mosquito problem was not a local one over two-thirds of our State.

A few communities had started a mosquito campaign on the accepted plan; oiling ponds and pools, covering water barrels, filling depressions, etc., and with excellent results so far as the elimination of local breeding areas was concerned; but the work was discredited when from time to time great swarms of mosquitoes made their appearance "worse than anything before known." The importance of determining the insects actually at fault was not realized and in consequence many an innocent pond was oiled or drained in the belief that it might possibly be responsible for the trouble, and a large percentage of the money spent failed to give any return of the kind expected. It is not fair to say that it was wasted, because the local improvements were

usually worth all they cost; but the desired result was not obtained, disappointment ensued and the belief in the possibility of mosquito control was weakened.

I have spoken of mosquito control rather than extermination, because I do not believe actual extermination is possible in the case of an insect that develops so rapidly and in such a great variety of places. There will always be careless people and there will often be unusual seasons that will give mosquitoes a chance to maintain themseves; but it is quite within our power to deprive them of their larger breeding areas and to reduce them to a point where they will cease to be obnoxious. Improvement of the salt marsh conditions will prevent the migrations, and will enable local communities to benefit by their enterprise in improving conditions. Were it not for the marsh mosquitoes, Montclair and South Orange would not even now need mosquito nettings!

While the work along shore occupied a large part of the time and force employed, because I considered this work the key to the situation, it did not prevent investigations in other directions. The cat-tail swamp along the Hackensack was thoroughly worked over and the very unexpected yet gratifying discovery was made that, as a mosquito producer, this may be practically ignored until it is permanently improved. It breeds no migratory forms and few of any other species. So the swamps along the Passaic were pretty thoroughly investigated and even in the Great Piece meadows the breeding areas were limited. One species breeds here that has the migratory habit developed to some extent, and this, *sylvestris,* does no doubt get into the immediately surrounding country. The Orange Mountain region was pretty thoroughly explored to determine what proportion of the mosquito supply they furnished for the surrounding townships. A part of the marsh area along the Delaware near Camden was investigated, but work there was necessarily abandoned for lack of funds. From Trenton to Bordentown a somewhat careful exploration was made and in Trenton and its vicinity the mosquito breeding places were located at the request of the Board of Health.

This brings up another branch of the work done. At the request of any community or organized body intending to do local work I always made a general survey of the territory to locate breeding places and make report. Between twenty and thirty localities were thus looked over and in a number of places conditions were much improved.

The breeding habits of the *Anopheles* or malaria carrying mosquitoes were kept in constant view, and every field agent had

general instructions to look out for them at all times. Especial work on these species was done at and near Delair in some choked swamp areas by Mr. Seal.

In order to make people practically acquainted with the character of the work that was needed, my assistants acted as superintendents at New Cape May, Beach Haven, Monmouth Beach, Rumson Neck and Newark, further details of which are elsewhere in the report.

It would be folly to say that a complete mosquito survey of the State has been made. There are considerable stretches of territory where no work has been done, simply because with the funds at my command it was impossible to cover them. There are areas, however, where mosquitoes do not figure as troublesome pests, or which are practically uninhabited because the mosquitoes make them so. It is quite possible that there may be some species that we have not yet found; but these are likely to be local and not troublesome. Only one species has eluded us in the larval stage and that occurs all over the State, sometimes quite commonly. The principal objects of the investigation have been attained; we know practically all our species, their habits and breeding places; we have determined by practical work and by experiment that control is possible at a reasonable cost, and there remains only the practical carrying out of the recommendations made.

It seems clear that the conditions are such as to demand State aid and, perhaps, State supervision for the control of the marsh breeding species; but even if this involved the expenditure of a million dollars from the State Treasury, the benefits to be derived in the increased value of the property, to say nothing of the increased comfort to the people, would repay the expenditure one hundred fold. One conservative gentleman who contributed $50 to a fund for cleaning out a large breeding area, told me that this outlay had increased the value of his property holdings by $10,000! Not all improvements will pay so well; but take the mosquito pest from Barnegat Bay and consider the resulting increase of visitors to that paradise for fishermen! The increase in value in that territory alone would pay for all the work that would have to be done along shore.

At the beginning of the investigation and even while the law authorizing it was under consideration in the legislature, the press with a few notable exceptions ridiculed the entire subject, and the mind of the public at large was not much better disposed. The general belief was that an impossibility was attempted and that the whole was a scheme that would result in the expenditure of public money without obvious result. It

MALARIA.

It was at first intended to include in the scope of the investigation a study of the malarial parasite and a series of experiments with mosquitoes that had fed upon the blood of malarial patients. To make these studies and experiments Dr. Herbert Parlin Johnson, then of Cambridge, Mass., who had had special training along these lines, was engaged during the summer of 1902. By the courtesy of the Board of Health at Harrison, a room in its building was assigned to Dr. Johnson, and a series of observations and experiments was begun. As the season advanced, however, it became obvious that far greater facilities were needed than the money in hand could secure, and further, that such experiments must be carried on in direct connection with a public hospital. As this phase of the subject was also engaging the attention of medical students and investigators, this line of work was abandoned. Dr. Johnson's work appears in my Report for 1902 and the acount of the malarial parasite and its development given elsewhere in this work is practically as prepared by him.

EXPERIMENTS.

It is impossible in any report of reasonable size to cover all the experiments made, in any detail. So many suggestions have been received and so many assertions were made in print, either as news reports or as advertisements, that it was necessary to test a great number lest in rejecting all, some really good things be missed. Many hours of patient work and watching and many pages of notes are recorded by a line or a word, or not at all, simply because the results were negative. It is easy to make a positive asertion, as, for instance, that in the migrating *sollicitans* female, ovaries do not develope; but it required the examination of several hundreds of specimens from widely separated localities to make it safe to speak so positively. It is the result of the work that is demanded, and which is given with just enough record of the observations and experiments made to show that it rests upon more than a bare assertion or belief.

ASSISTANTS.

In an investigation covering so great an area, when it is imperative that at one date several localities shall be under observation, no one man can do all the work. The one in charge

of the matter must depend upon others to see for him, to act for him and to conclude for him, as occasion may demand. He is at the mercy of his assistants at times, and upon their faithfulness and intelligence his results depend.

I believe that I have been singularly fortunate in this respect. I have had no reason to doubt the loyalty or honesty of any of the men who have acted or observed for me, and all of them have at all times endeavored to obtain the results expected of them; oftimes at much physical discomfort and under adverse conditions. Every man deserves credit for the work done by him, tho it be but a step toward the goal, and I wish to express both my obligation and gratitude to each of those that have aided me.

Throughout the investigation Mr. J. Turner Brakeley, of Bordentown, has given most important aid as a volunteer field observer, especially on such species as occur in the Pine belt of Ocean County, where he has a cranberry plantation. It was Mr. Brakeley who first found wrigglers in the leaves of the Pitcher-plant, *Saracenia purpurea* and worked out the life history of what proved to be a new species, now known as *Weyomyia smithii*. Incidentally, he demonstrated for the first time that they might be frozen and thawed out repeatedly without injury; also that their eggs might be laid in dry places. It was Mr. Brakeley, also, who demonstrated that *Culex melanurus* passed the winter in the larval stage, and in that investigation he tramped the bogs in sleet and rain storms in midwinter, and collected in ice-cold water until he was drenched and his fingers so benumbed with cold that he could no longer handle the collecting materials. But he persisted until his facts were established beyond peradventure, and, incidentally, he found not only eggs of *Culex canadensis* but the interesting point that they might hatch in the first days of February in ice-cold water and even in ice-covered pools. He found the larva of *Culex aurifer* and of *Corethrella brakeleyi*, species until then altogether unknown, and he was the first to breed *Corethra cinctipes*. With infinite patience he collected over his entire territory and noted details of his collections at great length. It is safe to say that he has found all the species that breed at Lahaway, where his plantations are situated, and this is of great importance when we find that in an experience of three years he never once found the larva of either *Culex sollicitans* or *C. cantator*, the dominant species throughout the pines. Much of my information concerning the habits of *Anopheles* larvæ and the hibernating habits of the adult also comes from Mr. Brakeley, and throughout this report frequent references are made to Mr. Brakeley's observa-

tions. It is rare to find so unselfish a devotion to the investigation of any subject, for Mr. Brakeley served without expectation of reward of any kind.

Mr. Edgar L. Dickerson has been associated with me throughout the investigation, even before the law providing for it was passed and while I was yet undecided whether I could reasonably claim a practical outcome for the study. Together we worked out the life history of *Culex sollicitans* in 1902, and thus gained the clue to a practical solution of the problem. We demonstrated for the first time that this species laid its eggs, not in water, but in the marsh mud, and that its vitality was sufficient to withstand a three months drying out.

Mr. Dickerson is now assistant to the State Entomologist, and his work in this investigation is incidental and arranged so as not to interfere with the duties of his office. Nevertheless, he has done a great deal of work in making special studies and in noting the material that came to hand. To him was also intrusted the test of the usefulness of certain materials supposed to be valuable as destroyers of larvæ, and especially the experiments with the sulphate of copper. The results of these tests are interesting and are elsewhere given. Special mention should be made also of the fact that the dissections for salivary glands and other internal structures of the mosquito were made by Mr. Dickerson.

Mr. Hermann H. Brehme has been associated with the investigation from the time funds to make it became available, and his assignments have been in general the salt marsh areas. No one has a better knowledge of this kind of territory and it would have been impossible to get a better man for the work. Mr. Brehme has had assignments inland, chiefly along the first range of the Orange Mountains; but his main work has been along shore, which he has covered from Newark to Seven Mile Beach with scarcely a break.

During the early part of the season of 1904 his assignment was the practical direction and supervision of the work done, first at Monmouth Beach and afterward at Newark. The experimental work at Newark in 1903 was laid out by him and practically the entire scheme of the Newark drainage, comprising almost 400,000 feet or over sixty-five miles of ditching, is his work. As to its effectiveness there is no question. Mr. Brehme's work will be frequently referred to in the body of the report.

Mr. John A. Grossbeck began field work early in 1903, and served throughout the season making collections and surveys at various points in the State. Though he did some salt marsh work, nevertheless his principal assignments were to interior points and especially the valleys of the Hackensack and Passaic

including in the survey the Great Piece Meadows. Late in the season he was transferred to New Brunswick and, throughout the winter worked as Laboratory assistant in arranging and classifying the immense mass of material that had been gathered during the summer. It was also his task to prepare the specimens for microscopic study and to make many of the drawings which illustrate this report. During the summer of 1904, his work in the Laboratory was continued, and he had the general supervision of the breeding jars and material that was brought in for study. His field assignments were for special collections to complete our knowledge of species yet imperfectly known. In the preparation of the present report Mr. Grossbeck is responsible for the descriptions of the larvæ and adults, the details of which he also illustrates with each species. Altogether the work owes much of its completeness to his care and patient accuracy.

Throughout the work I have had the co-operation of Mr. William P. Seal, of Delair, New Jersey; most of the time as a volunteer, during the summer of 1903 as a member of the staff especially intrusted with the questions concerning the relations of fish to mosquito larvæ. Incidentally also, the value of pollywogs of both toads and frogs was determined experimentally and collections of all sorts of aquatic creatures were made. Mr. Seal has had a large practical experience in fish culture with the United States Fish Commission and as a collector, hence his contributions to the work have been of great value. He was one of the first to insist that some mosquitoes at least must lay their eggs in damp depressions to account reasonably for the appearance of wrigglers so soon after they become filled.

During the summer of 1903, Messrs. Charles W. Wagner, of Elizabeth, and John Mellor, of New York City, students in the Engineering course at Rutgers College, were sent into the field to study the questions connected with salt marsh drainage and the available methods of dealing with the breeding places of the salt marsh species. Their work began in the meadows at the mouth of the Raritan River, for which a complete scheme of drainage was prepared. The conditions along the Barnegat shore from Point Pleasant to the New Inlet at Great Bay were carefully studied, and at Beach Haven a scheme for drainage to relieve local conditions was laid out and its carrying out was supervised so far as the work was done. Thereafter these gentlemen joined Mr. Viereck at Cape May and, acting on his information as to breeding places, worked out a practical and inexpensive scheme for bettering conditions there. The report on the latter place makes interesting reading and places into the hands

of the community there an unequaled opportunity for practical and effective work.

For a month in 1904 Mr. Mellor was again employed, this time to make a rough survey of the territory along the Bay Shore from Dennis Creek to Salem Creek and up the larger streams like the Cohansey to determine first, how far up these creeks the salt marsh forms could breed, and second, the general methods that would have to be adopted in dealing with the species in that territory.

The work done by these gentlemen appears in more detail elsewhere in the report.

Mr. Henry L. Viereck, of Philadelphia, Pa., was in the service during the summer of 1904, and stationed, most of the time, at Cape May. Excursions were made to shore points further north and to points on the Delaware River; but the place where the chief work was done was at Cape May. The problems assigned to Mr. Viereck for study were the egg-laying habits of the marsh mosquitoes in greater detail than before known, the length of life of a brood, the number of broods and other facts connected with the species. A series of experiments was also made with several species of pool and ditch fish to determine their effect upon mosquito larvæ and their relative value as destroyers. Incidentally, the parasitic worm that infests the body of the mosquito was observed and the percentage of infested specimens was determined.

With these especial points to be determined was associated a survey of the Cape area for breeding places, to determine how the pest could be controlled in the cheapest and most complete manner.

To ascertain as accurately as possible whether the marsh mosquitoes have a preference as to breeding points, Mr. Viereck studied the marsh itself and its flora, especially where breeding pools were most plentiful. It was found, in brief, that there was some relation between the flora and the abundance of the wrigglers; but that the range of breeding places was greater than any one botanical area.

In general the results were satisfactory and a good collection and series of notes were obtained from which some of the facts stated in this report are derived.

The question, what use are mosquitoes? is usually answered by a reference to the habits of the larvæ, which are said to be scavengers feeding on the micro-organisms that cause foulness in water. Unfortunately wrigglers are often found in the clearest springs, and some species never occur in any water that is in the least foul and then only in such small numbers that the con-

dition of the water could not by any stretch of imagination be considered as the result of the larval influence. This made it somewhat important to ascertain in a general way something about the food of mosquito larvæ. It was noted also that certain of the species never bred except on the salt marsh, and the question arose, what food or other conditions occur on these marshes that are not found further inland.

To determine some of these points Mr. Horatio N. Parker, Inspector to the Montclair Board of Health, was asked and kindly consented to examine the stomach contents of a series of wrigglers that were sent to him for that purpose. The result is somewhat disappointing, inasmuch as it does not seem to give the real clue to the conditions which make the salt marsh species dependent upon salt marsh conditions. Mr. Parker's findings are of great interest nevertheless and form a part of this report.

During the summer of 1903 I engaged the services of Mr. E. Brehme, of Newark, as an assistant in the local investigation. He looked after the mosquito cages then on the meadows, and supplied what material was needed for the observations for which they were intended. He kept notes of the local developments on the meadows and collected from Newark back along the first ridge of the Orange Mountains, adults as well as larvæ, to determine the range of the salt marsh species and the character of the species that actually bred where the meadow species were dominant. Part of the general survey for marsh breeding places near Jersey City was also intrusted to him, as well as the collections along the edge of the marsh area to determine how far inland larvæ of *sollicitans* and *cantator* could be found.

That some mosquitoes hibernate as adults was, of course, well established; but when the investigation showed that, where mosquitoes occurred at all, almost every cellar had a winter population that sometimes ran into the hundreds, the question arose whether there was not some way of destroying them while they were dormant and thus lessening the early crop. It is safe to say that 90 per cent. of the hibernating forms in a city, town or village, may be found in house cellars, and the problem was therefore an important one, especially as the *Anopheles* are among those that hibernate in this way. It is known, of course, that Hydrocyanic acid gas would kill; but this is so deadly in character that its universal use is prohibited. Sulphur is equally effective when properly used; but its effect upon fabrics and metals limited its application and it was desirable to get some simple, inexpensive material, harmless to mankind yet deadly to mosquitoes.

This phase of the investigation was intrusted to Mr. George J. Keller, of Newark, a graduate in Pharmacy, who is also interested in some phases of Entomology. Mr. Keller attacked the problem early in March and the results of his cellar studies in and near Newark make interesting reading. After trying a great variety of materials alone and in combination, Mr. Keller at last settled upon powdered *Datura stramonium* and succeeded in producing the desired effect. *Datura stramonium* is the common "Jimpson weed," known as producing a narcotic poison, but useful in asthmatic affections. The results of Mr. Keller's work form part of this report.

From April, 1903, to May, 1904, Mr. Clarence Van Duersen was field and office assistant. He was largely responsible for the care of the breeding jars, of which there were sometimes over twenty, each with a lively wriggler population from which adults were issuing almost daily. Mounting these after they had been noted up was no small task, and the alcoholic material preserved in connection with the breedings ran into hundreds of vials, all of which it was necessary to label for future study. In the field he was chiefly employed near New Brunswick and succeeded not only in finding the larvæ of two species that had never before been bred; but in discovering two species that had not even been described. From June to October 31, 1904, Mr. Harold O. Marsh replaced Mr. Van Duersen, doing much the same kind of work.

During the seasons of 1902 and 1903, Mr. Otto Buchholz, of Elizabeth, made a series of collections of mosquito specimens found near his house, in the streets and indoors. The object of the collections was to determine the species that were troublesome both indoors and out and whether, as the season advanced, there was any change in the mosquito population. The collections were therefore made at five-day intervals throughout the season, indoors and out, and a very clear idea was obtained of the character of the species flying.

CHAPTER II.

MOSQUITO STRUCTURES AND PECULIARITIES.

THE ADULT STRUCTURES.

In order to recognize the difference between mosquitoes so as to determine which species is under examination, it is necessary to know a little about the general make-up of the insects. The determination of the particular species that causes the trouble is often a matter of serious importance because, if either of the salt marsh forms prove to be in fault at some point away from the coast, not all the local work, no matter how thorough, can produce a cure. If *sylvestris* be the offender, some fresh water swamp area falls under suspicion; but if it be *pipiens* the specimens are home grown and probably from close to the point where they are most troublesome. *Anopheles*, when found, suggests sunken lot areas or pools in low meadows, or a sluggish stream or ditch, and thus the determination of the species at fault should always be the necessary preliminary to the beginning of practical work; fighting in the dark never pays and may result in more harm than good.

The figure (1) on page 15 should be compared in this connection, and from that it appears that a mosquito body is divided up into three rather well marked parts or sections: the head, the thorax and the abdomen. The head bears the eyes, the feelers and the mouth parts. The thorax bears the wings and legs, or organs of locomotion. The abdomen has no appendages; but in the male it has a pair of claspers at the tip, and in the female this part is drawn out into a flexible point or tube through which the egg is laid—an ovipositor.

The most prominent structure of the head is the beak, which is usually less than half and never (in our species) more than two-thirds as long as the entire body. It may be and usually is of the same general color as the body, but in some cases it has a very distinct white band at about its middle and that is one of those readily noticeable features that can be made use of in popular classification. It needs only a magnifying glass enlarging two or three diameters to bring out this and most of the other points here used, very clearly. The character of the biting structures that lie within the beak is elsewhere discussed. Next to the beak, at the base, are the palpi or mouth feelers; very

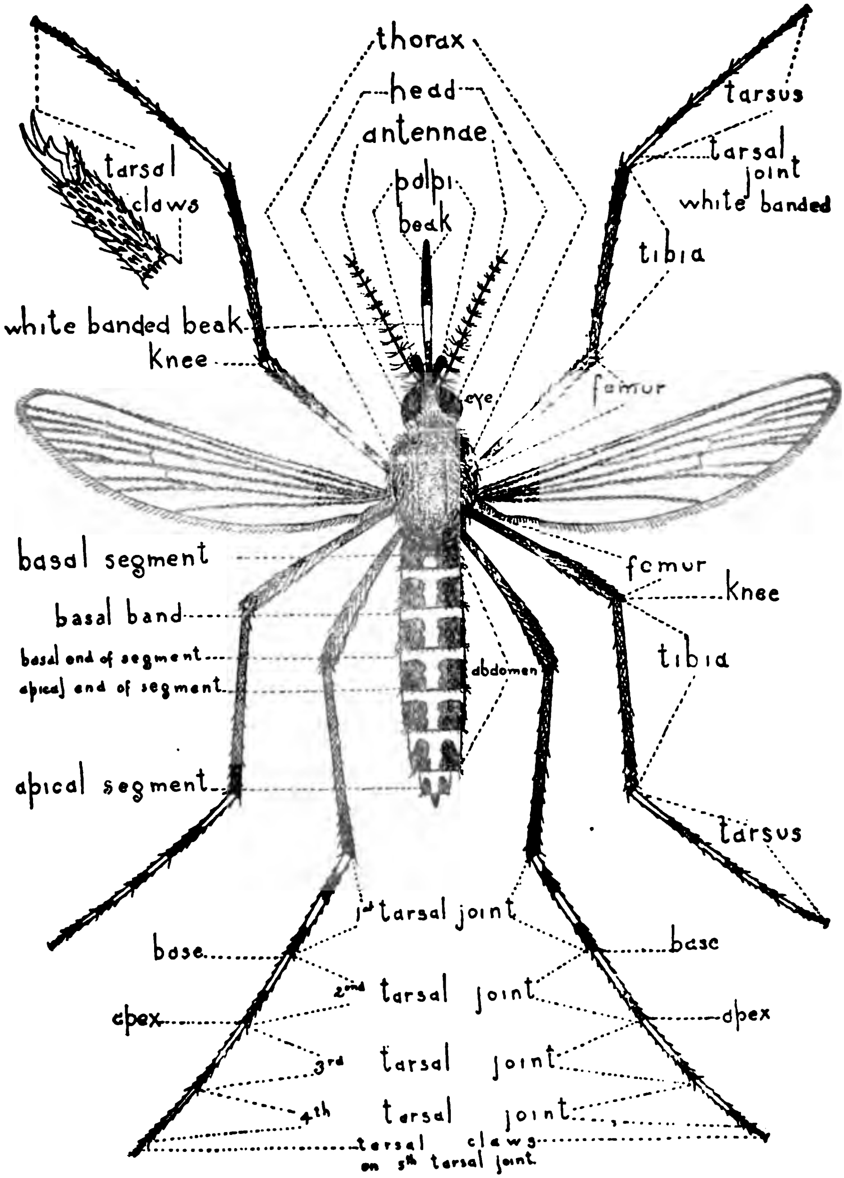

Figure 1.

An adult mosquito with all the parts that are used in classification named. (Original.)

small, inconspicuous jointed structures in the female; but prominent features in the males of most species, extending to the tip of the beak or even beyond it. In this sex the joints become thicker toward the tip and the terminal joints have long tuftings of hair on the inside. Just above the beak and between the eyes are the antennæ or feelers; long, jointed organs, that are usually shorter than the beak. In the female the joints making up the antennæ are slender, cylindrical, very much alike, and set with a few long hairs, making a sort of ring. In the male, on the other hand, the joints are shorter at the base, cup-shaped, one cup partly fitting into the other and around the rim of the cup are long, silky hairs, so that, under the ordinary glass, the feeler appears to be feathered or like a plume. Above the cup joints are two long, slender segments, which are not specially modified.

The eyes occupy most of the side and top of the head, but offer nothing of importance for our purpose. Those who have a microscope at command will find the scales on the vertex to be interesting and for some species quite characteristic.

The thorax is usually the stoutest part of the insect body, and its color gives the prevailing tint to the insect. As a rule it is of one color or uniform, but some of our species have stripes and lines of blue, golden brown or white, and one of them is obscurely spotted. Sometimes the sides are quite different from the top or dorsum, and we get the appearance of a broad, dusky stripe down the middle. In some species the surface is smoothly set with fine hair or scales; but in others there is an admixture of long stout hair and we get a spiny or bristly appearance. Sometimes these bristles are arranged in regular rows or lines, and altogether there is quite a little difference in appearance.

There is, attached at the sides, a pair of narrow wings, veined nearly as in the figure, and these are transparent and unspotted in the majority of our species. In general, when the wings are spotted or otherwise marked, the insect may be set down as *Anopheles*. We have two species of *Culex* in which the wings are a little mottled, but these are rare and small, not likely under ordinary circumstances to come to the attention of collectors. Along the veins and the lower margin of the wing is a series of very pretty scales; but these require a microscope for their appreciation.

The legs are long, slender structures made up of a number of pieces or parts. At the base is the femur or thigh, attached to the body by means of a small hinge joint or coxa. This femur is sometimes decidedly lighter in color on the side next to the body. The tibia or shank is attached by its base to the tip of the femur and is usually uniform in color; sometimes, however, it

becomes darker toward the tip and occasionally it is banded. The tarsi or feet are made up of five joints or segments and those on the hind legs are longer than those on the anterior or middle legs. Variations in the tarsi are easily seen and their markings and bandings are good for easy recognition. Usually, when the tarsi are banded, each joint has a white or whitish ring at the base only; rarely the joints are white at both base and tip, forming a broad double band at each incision; yet more rarely there may be a white band at the middle of one or the other of the segments. Occasionally one or more of the joints of the hind tarsi may be entirely white.

At the tip of each tarsus or foot is a pair of small claws which are interesting under the microscope. Some of these claws are toothed and some are not and those on the different feet of one species may differ. Furthermore, the male usually differs from the female and has the anterior claw-joint quite different from those of any similar joint in the other sex. These points will be found illustrated under specific headings and are not important for rough determinations.

The abdomen may be uniform in color or it may be banded. If banded, the ring may be at the base or at the tip of the segment. The band may be broad or it may be narrow; it may be even or notched, or otherwise modified. In only one of our species is there a stripe down the middle of the upper side.

Given a mosquito captured in good condition so that all its parts may be readily examined with a glass, the first point to ascertain is whether the tarsi are even in color or ringed with white. If they are white ringed, the beak must be next inspected to determine whether that is uniform in color or has a white space at or near the middle; assuming that it has not, the feet must be again examined to find whether the joints are ringed at base only or at base and tip, and whether any of the joints are entirely white. The thorax must be examined for spots, lines or stripes, and finally the character of the abdominal banding must be determined.

It sounds formidable enough and it may be a little slow at first, but after a little practice all of these points are determined at a single glance, and the insect may be placed at once with its near neighbors, from which discrimination is usually easy.

STRUCTURE OF THE LARVA.

The mosquito larva, wiggler or wriggler, is a slender creature usually whitish or gray in color, the head and thoracic segments enlarged, usually twice as broad as the following or abdominal

segments. On the eighth of these segments is a tube or siphon of variable length and through this the insect breathes. As it usually gets its air supply from above the water surface its natural position is head down and tail up. It has no legs or other organs of locomotion and moves by a series of jerks or wriggles which drive it rapidly downward or irregularly away from the point of disturbance.

Figure 2 on page 19 is a diagrammatic representation of a *Culex* larva, and this will serve very well for a type of all save the few species of *Anopheles* and *Corethra* group. The parts shown there are all of more or less importance in classification and need either a good hand lens or a compound microscope for their discrimination.

The head is usually wider than the body segments and narrower than those of the thorax; but this varies in each direction, the head in some forms being the widest portion of the larva. It may be either lighter or darker in color than the body and may be uniform or maculate. When maculate, the markings are very constant and form a reliable basis for the recognition of the species. At the sides of the head, the eyes are the most prominent organs; usually blackish and so much alike in the species as to be unavailable for classification.

Nearer to the front of the head are the antennæ—one on each side—and these may be long or short, straight or curved, and if curved, it may be to the out or to the inside, or there may even be a double curve; they may be of equal thickness throughout, or there may be a thickening at base, with an abrupt narrowing at or near the midde, forming a set-off. At or about this place there is usually also a tuft of hair, which may be dense or thin, long or short. These features are of great importance in classification and some species are recognizable at once by the form of the antenna alone. At the tip there is usually a very small articulated joint or process and a number of longer or shorter spines and hair.

When we watch a wriggler closely we find that the mouth structures are in constant motion and that, apparently, there is a pair of brushes composed of long, fine hair. These mouth brushes seen under the microscope are excellent devices for gathering in the minute organisms upon which the larvæ feed; sometimes the hair in the brushes is all simple, sometimes some of it is pectinated or toothed like a comb, so that, however minute the creature, it may be drawn in. These brushes form part of the maxillary structure of the mouth. Just above them are the minute mandibles or jaws, with their complicated teeth and edges adapted for tearing and crushing, for the ordinary wriggler

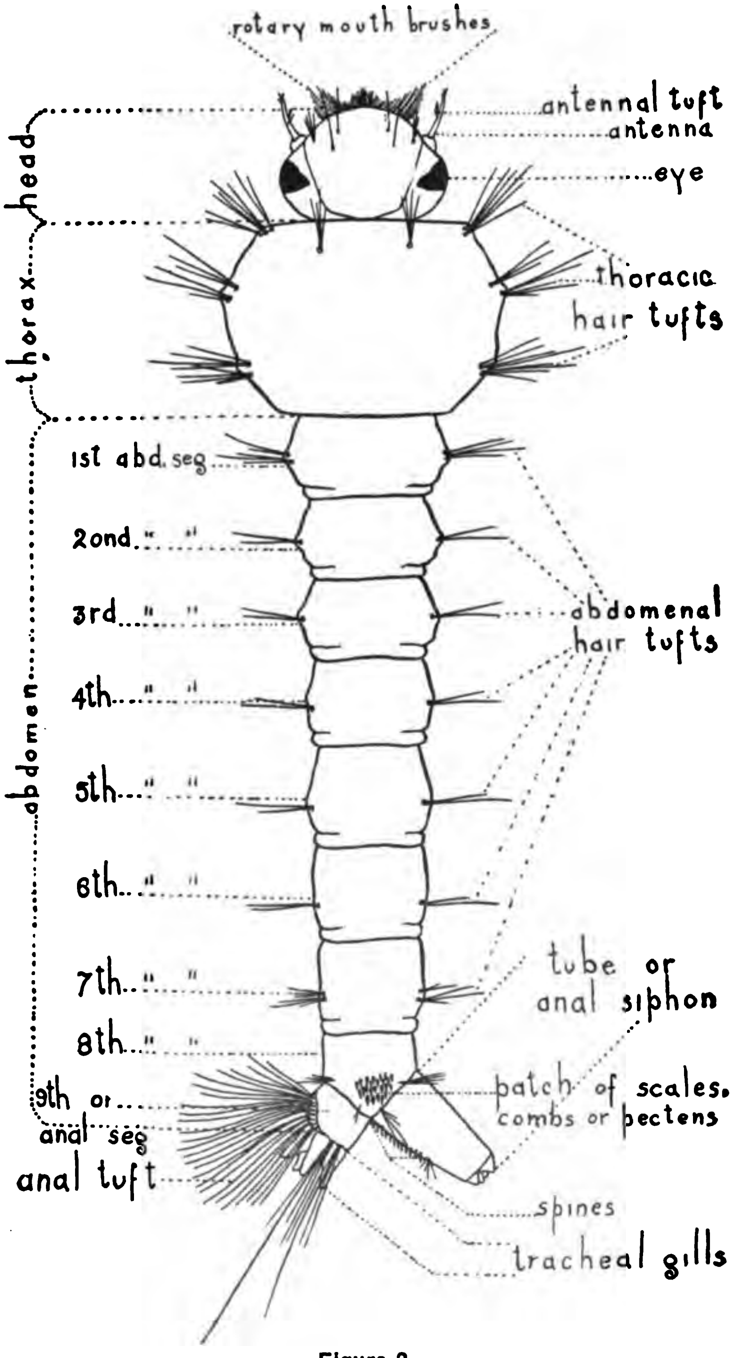

Figure 2.

A mosquito larva with the parts that are used in classification named. (Original.)

is really carnivorous in type. At the outside of the brushes are the remaining maxillary structures, usually lumped under the term palpi. In the middle of the under side is a triangular or quadrate brown plate, the mentum, which represents the labium or lower lip. The edges of this mentum are toothed or serrated and the variations assist in the determination of the species. The variations in these mouth structures are shown on the plates illustrating the different larvæ. They cannot be seen except with a compound microscope after proper dissection and they are not essential to a recognition of the larva.

The thoracic segments are so massed together that they are not easily distinguished except at the sides, where tubercles, giving rise to hair tufts, mark their edges. Except for its general shape and proportion the thorax offers nothing of importance for ready classification.

Then follows a series of seven segments, which usually resemble each other closely and which differ little in the species except for the length of the hair tuftings which come from the sides. On the eighth segment there is on each side a patch of scales with a definite arrangement, the scales all very much alike, yet not alike for any two species. The character of this patch of scales or comb and the shape of the individual scales is of the greatest importance in classification and some closely allied species are distinguished with certainty only by a reference to it. The arrangement of the scales and their form is shown for each species.

The anal tube or siphon is also a process of the eighth segment, and this varies in length and in form; there is more variation here, within specific limits, than in some other structures, and yet there is a characteristic appearance in some cases that, in connection with the antenna, decides that species at once. On the under surface of this siphon is a double row of spines extending from base to or not much beyond the middle and these spines are also characteristic in shape and reasonably constant in number. The term pecten is applied to these series of spines and that term in the diagram is erroneously referred to the scale patch.

The function of this tube is to enable the larva to reach through the surface of the water to the outer air to get a supply of oxygen, and for most of the species this is the only way in which it can be obtained. Cut off access to the air and the larva drowns, like any other air-breathing animal. By putting oil on the surface of a pool inhabited by mosquito larvæ, access to the air is shut off and they die.

The ninth abdominal segment is very small, furnished with a series of long hair tufts arising from a ridged or barred area. It is also furnished with one or two pairs of anal tracheal gills, varying much in appearance as between species and somewhat in length, within specific limits. In by far the greater number of species these gills have no breathing function whatever, and under the microscope no trace of trachea or breathing tubes are seen. But there are a few species in which these organs are functional, where the trachea are developed and where the larva can get all the oxygen it needs from the water itself. In the case of the pitcher-plant mosquito, which lives a long time in the larval state, specimens were kept in a jar under an oil film for thirteen days without coming to harm.

In attempting to identify mosquito larva the first point to be regarded is the antenna; has it an off-set or not? Next, whichever way the decision goes, the length of the breathing tube and its general proportion comes into question. Then the maculation of the head and beyond that the scale-patch and pecten must be referred to. It is not so easy as identifying the adults; but on the other hand the habits of the larvæ and the place and time where found often give a clue to the species that serves for ready identification: *i. e.,* if the larvæ were found on a salt marsh, they must be one of four species, which are easily distinguishable. If they were taken upland these species are cut out from consideration, and so, by taking habits as well as structure into account, a very close approximation to the true species may be made in most instances by any reasonably persistent student.

THE PUPAL STRUCTURE.

The term pupa is applied to that stage in the mosquito life cycle which is intermediate between the larva or wriggler form and the adult mosquito. In this stage no food is taken, though the insect yet remains a water inhabitant. There is no resemblance to the original larval condition and, at first sight, not much to the future adult. We have a hunched up creature without obvious organs of any kind that floats on the surface of the water when undisturbed and darts wildly and aimlessly through the water with a jerky motion propelled by a pair of flattened gills or swimming paddles situated at the end of the abdomen.

If we examine this pupa more closely, looking at it from the side, we begin to make out something of the future adult. The flexible abdomen is more like that of the wriggler, except that it does not end in a breathing tube and does have the flattened

terminal gills or paddles. If we examine the thickened or hunched up end we find ourselves able to trace the outlines of the future adult all covered by the pupal shell and glued together closely.

We make out a black spot where the future eye will be found, and curving above and behind it we see the future antenna, the joints already indicated. The wing-pads, forming the largest part of the enlargement, are plainly to be recognized, and, folded up against them so closely as to almost defy separate recognition, are the cases for the long, jointed legs.

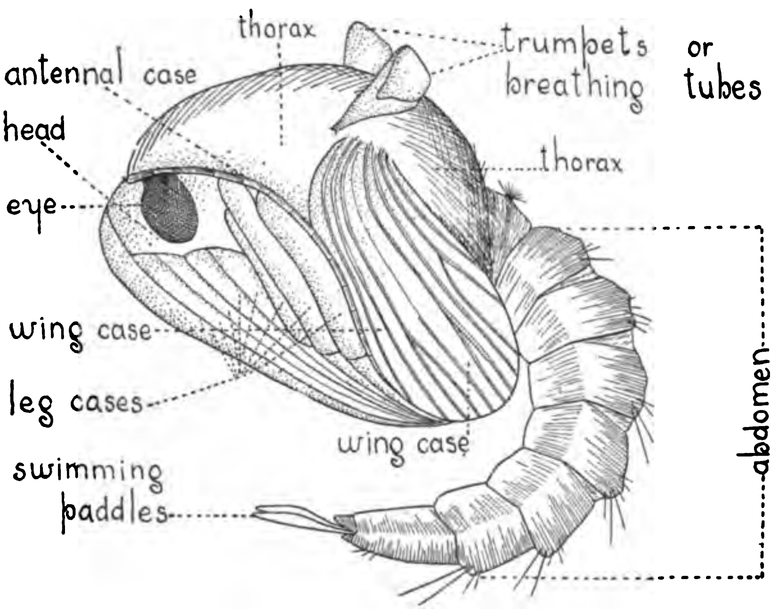

Figure 3.

A mosquito pupa with the parts named. (Original.)

On the upper surface of the enlarged portion are two breathing tubes, varying in length and form, through which the insect gets its supply of air. Although still an aquatic creature which will die if removed from the water, it is even more dependent upon atmospheric air than the larva, for some larvae have gill structures that enable them to secure oxygen directly from the water. Only in the *Corethrinæ*, which are not really true mosquitoes at all, are the pupæ able to remain submerged for any length of time.

It follows that oily coverings on the water surface are quite as effective against the pupa as against the larva. As the pupa

does not feed, no poisons that act through the alimentary canal, either directly or indirectly, affect it, hence some materials that act satisfactorily on the larva are ineffective as against the pupa; a point which will be further touched upon in another place.

The pupal stage is short, as a rule, lasting less than a day in some cases in mid-summer when droughty conditions prevail. Usually two to four days may be considered normal, but in cool weather a week or even two weeks is not unusual.

There is little difference between pupæ within generic limits—at all events nothing that can be readily observed; hence practically no attention is paid to this stage in the descriptive work. Only types of each marked variation are figured.

When the adult is fully developed within the pupa the latter becomes less active; it loses its curved position and tends to straighten out; finally the skin bursts along the middle of the back, and the adult rises up almost vertically without apparent effort, seeming really to ooze out of the envelope until the wings are free. Then the long legs are carefully withdrawn and the mosquito rests, fully developed but very soft and moist, on a boat formed of the pupal shell. In a few minutes the drying process is completed and the insect flies away.

THE MOSQUITO WING.

The wings of mosquitoes are long and narrow, fringed with characteristic scales, the veins are set with scales of two or three kinds along their course and, in the spotted winged forms, the marks are usually produced by dark colored, massed scales. This is one of the characteristics of the mosquito family, for very few, comparatively, of the flies have scaly wings.

On the upper surface the scales are usualy of a pointed, feather shape, on the under side they are more usually truncated. They are arranged along the veins in a feathered series, all pointing to the edge of the wing. Under the microscope the transparent surface of the wing is seen to be set with small spinous processes, which, by interfering with the light rays, give rise to the iridescent appearance.

The venation or arrangement and course of the veins is constant throughout the family, though there is some variation in the length of the forks. The form of the wing scales varies sufficiently to make them of some importance in classification; but that point will be more fully referred to in the systematic portion of this work.

In the figures here given of *Culex* and *Anopheles,* the names of the veins and cells are as given in Nuttall & Shipley's papers on *Anopheles,* and they in turn follow Comstock and Needham in essentials.

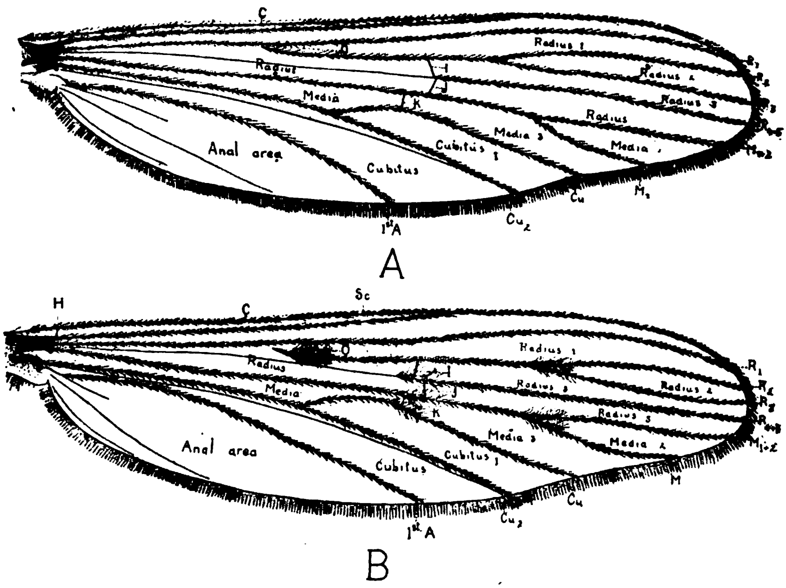

Figure 4.

A, represents the wing of *Culex pipiens;* B, that of *Anopheles maculipennis.* The lettering is the same in both and means as follows: *C,* costa; *Sc,* subcosta; *R,* radius, the numbers referring to the branches; *M,* media, the numbers referring to the branches; *Cu,* cubitus, the numbers referring to the branches; *A,* anal; *O,* cross vein between radius 1 and radius 2; *I,* cross vein between radius 2 and radius 4 and 6; *J,* cross vein between radial and medial systems; *K,* cross vein between medial and cubital systems; the names of the cells are written out full. (Original.)

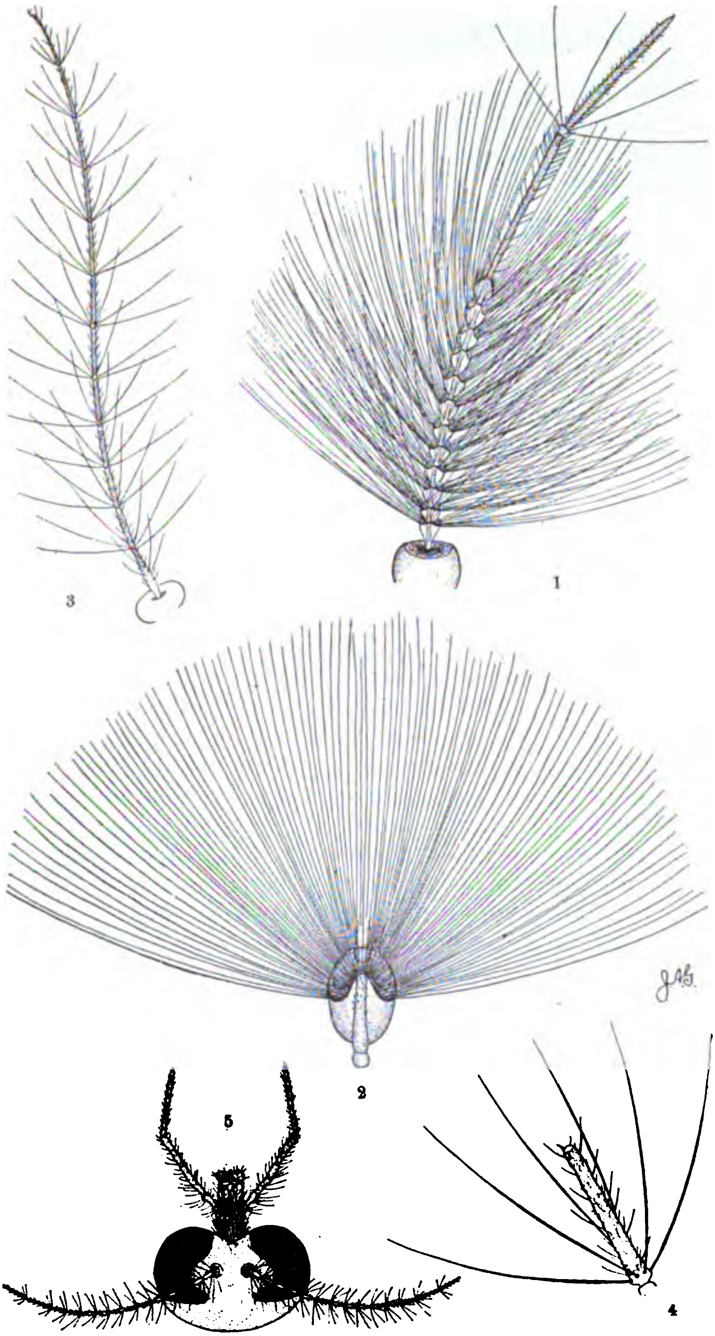

Figure 5.

Antennæ of mosquitoes: 1, of male *C. canadensis;* 2, a single segment, further enlarged; 3, of female *C. canadensis;* 4, a single segment, further enlarged; 5, entire head of *Sayomyia albipes.* (Original.)

CHAPTER III.

HABITS OF MOSQUITOES.

THE MOSQUITO BITE.

No questions are more frequently asked than: Why does a mosquito bite? Why does it produce the pain? Does a mosquito feed on anything other than blood? Must a mosquito have blood before it can reproduce? Does a mosquito bite more than once?

Answering these in the inverse order, there is no doubt that a mosquito will bite practically as often as it gets a chance to do so. Actual observations on *Culex cantator* and *C. sollicitans* has proved that a full meal of blood is completely digested in less than three days. *Anopheles* in captivity will bite daily for several days in succession and hungrily if made to fast longer than forty-eight hours. *Culex sollicitans* will bite after all the eggs are laid and sheer blood-thirst is the only excuse. These are all matters of direct observation and experiment and, based upon these observations and upon others that are recorded, it seems safe to say that mosquitoes that suck blood at all, will do so as often as opportunity serves.

As to whether blood is a necessary food to enable a female mosquito to mature her eggs there is yet considerable doubt. It is certainly proved within my own experience that *Culex pipiens* may oviposit without food other than that which could be found under the net covering a common wooden pail in which the parent developed. It is certain too, that there are long stretches of salt marsh breeding areas on the New Jersey Coast where mosquitoes occur by the million, where the foot of man does not touch once a year, where no warm-blooded things save a few birds abide, and where blood is absolutely unobtainable. Of course, a large percentage of these salt marsh breeders migrates inland and feeds bountifully; but none of these migrants seem to be fertile and the blood food produces no developing ovaries. On the other hand, the vast majority of specimens in which ovaries were found to be well developed, showed traces of blood food in the stomach. This statement should be qualified, however, so as to apply to *C. sollicitans* only; in *C. cantator* there is usually no trace of food observable to the naked eye when ovaries are fully developed.

Very few direct experiments were made on this point with other than the species above mentioned; but published records indicate that in captivity some species will not develop eggs or lay them until after a meal of blood. Whether that would hold equally true of the same species under entirely natural conditions, may be considered questionable. Incidentally it may be said that not only are all warm-blooded animals and all birds attacked by mosquitoes, but the reptiles also, where they afford an opening. On the whole, the balance of evidence is perhaps against the idea that blood is a necessity for egg development. This is further indicated by the fact that *Anopheles* goes into hibernation without having fed, and that there are few records of biting early in the season, before these hibernating forms lay their eggs to produce the first brood of larvæ. I do not mean to assert that *Anopheles* has never been observed biting in spring; only that the habit is exceptional and that, so far as the general observations go, hibernating female *Anopheles* are not dependant upon a blood meal to enable them to reproduce their kind. Dr. Johnson records that *Anopheles* in spring bites even during the day, but I have not observed that.

That mosquitoes feed upon vegetable juices as well as blood is certain. As to the males it must be so, if they feed at all; for their mouth structures are not adapted to puncture the skin or to suck blood. Besides, I have observed them in great number in wild cherry blossoms in the early evening, apparently busied in getting at the nectar. Females have been observed at the same time; but apparently these abandoned the vegetable food readily, when the animal odor advised them of something more to their taste. In captivity all species feed readily on the juices of almost any fruit that is offered. Banana, apple, pear and plum have been tried by me or under my direction and all answer equally well.

In nature, specimens are often taken with the stomach filled by a colorless liquid like plant nectar, and, on the other hand, in *sollicitans,* I have often found it filled by a mass which I could not distinguish from thin marsh mud. The conclusion is that, on the whole mosquitoes are not dependent upon blood food to sustain life. It is pertinent and yet seems a little out of place, to add to this that some species of mosquitoes have never been known to attack a warm-blooded animal no matter how well the opportunity served. Others seem to bite only under exceptional circumstances and almost every species has some peculiarity of its own to distinguish its method of attack.

A mosquito bites, primarily to obtain food; there is neither malice nor venom in the intent, whatever there may be in the act. Theoretically there would seem to be no reason why there

should be any pain from the introduction of the minute lancets of the insects, and the small amount of blood-letting is usually a benefit rather than otherwise. Unfortunately, however, in its normal condition the human blood is too much inclined to clot to be taken unchanged into the mosquito stomach; hence, when the insect bites, a minute droplet of poison is introduced, whose function it is to thin out the fluid and make it more suitable for mosquito digestion. It is this poison that sets up the inflammation and produces the irritation or swelling. If we make a puncture wound with a fine needle, a small droplet of blood will exude which will almost at once harden into a clot, and if we attempt a little later to break that clot, we will find it tough and hard to disintegrate. If we allow a mosquito to bite until it is fully gorged and then smash it, we find that the blood from the gorged abdomen is much more fluid and spreads out thin. If we further allow it to dry, there will be no clot; but a thin spread of material which is brittle and breaks readily into little fragments.

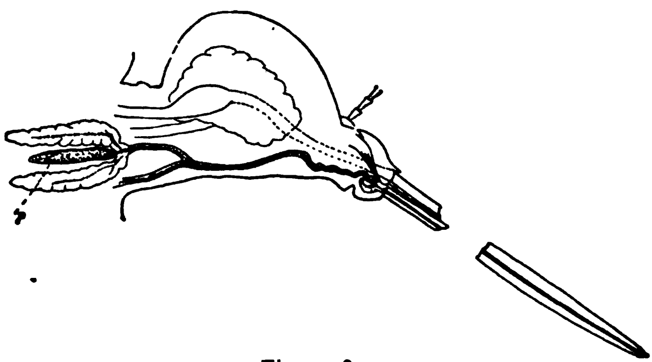

Figure 6.

Section of head of *Culex*, showing location of poison gland at P. (After Macloskie, from Howard "Mosquitoes," by permission.)

The pain is caused entirely by the action of the poison in breaking up the blood, and as the first act of a biting mosquito is to introduce this poison into the wound, the pain and inflammation will be the same, whether the insect gets its meal or not. In fact, it has been said that if a mosquito be allowed to suck its fill and then fly, the bite will not itch, and there is just a basis of justification for this. The poison introduced will act upon just so much blood, and if that be absorbed with the poison by the insect, little or nothing will be left in the wound. If, however, the mosquito be killed as soon as the poison is introduced,

the latter will have to be absorbed by the human system and the disintegrated blood mass with it. This is the basis of fact behind the popular belief that a bite does not hurt if you allow a mosquito to complete its meal and withdraw the lancets naturally.

Susceptibility to mosquito poisoning varies enormously. Some persons do not even notice mosquitoes biting under ordinary conditions, though they may be honestly unaware of their exemption. I remember enjoying a drive with a man who told me of his sufferings from mosquito bites, while a specimen was deliberately filling itself from his lower lip, not in the least disturbed by the talk. Mr. Brehme does not notice marsh mosquito attacks at all; but he bolts green head flies. Mr. Brakeley captures *perturbans* by looking at his ankles occasionally and bottling any specimens he may see there. It is only when he sees them that he knows they are present and yet *perturbans* is a hard biter!

On the other hand, I have met many persons to whom even a single bite was a torture and who were in positive agony during a stay along shore. In such persons puffy swellings appear and cover an area an inch or more in diameter from a single bite. When bites are at all numerous the suffering is intense and the appearance pitiable. Between these extremes all intergrades are found; but I have never found a man yet, who, in a mosquito region, had not at times been driven out by mosquitoes.

Personally the insects bother me, but the pain is usually temporary and, if I refrain from scratching, a matter of a few minutes only. And this brings up the matter of species; for a man may be exempt as against one species and not another. Boatmen and others along shore, who never know whether mosquitoes are present in their own territory, suffer severely and swear loudly when they get within range of the inland mosquitoes; and the contrary is equally true.

Nowadays I scarcely mind *sollicitans* at all, and *cantator* does not worry me much. *C. pipiens* is more troublesome and its bites sometimes cause distinct swellings; but I can sleep through any attack save that of *Anopheles*. This has a different song and a different manner of attack, and somehow I do not feel at ease near it. I will awaken at any time to a specimen buzzing about, where I would not mind any species of *Culex*. These are, of course, personal characteristics and may not apply to any other individual. The case is cited merely to show that there is a difference between the virus of the species and between the susceptibility of individuals.

There is also a difference in the manner of attack. Some species hover about for a long time, selecting a place to puncture; others dart in at once, giving scarcely any notice of their arrival; some fly at the least disturbance, while others can scarcely be driven off when once they have tasted blood. The peculiarities so far as they have been observed, will be noted under specific headings.

During the summer of 1904 I had the pleasure of being bitten by *Stegomia fasciata,* the yellow fever mosquito, in Georgia. This species has the singing habit developed in the most aggravated form and will hover, as it seems, for hours before determining to bite. Ordinarily I can feel a mosquito when it alights anywhere on my face or hands; but these little fellows I could not feel. I knew when one had lit; but absolutely could not locate it. Nor was there any immediate sensation of pain with the bite. In fact the bite itself was not felt; but gradually attention was directed to a sensation of pain coming on slowly and increasing in intensity until it reached a point quite as acute as anything I ever felt in New Jersey.

It would seem as though I ought to be used to all sorts of mosquito bites by this time; but the persistent singing, the inability to "swat" the culprits and the gradual development of bites on every exposed portion of the body, effectually destroyed sleep for that night.

HOW A MOSQUITO BITES.

If we watch a mosquito after it has settled for a meal, we will observe that the head comes ever nearer to the skin, but that the beak itself is not forced into it; on the contrary we may see that the beak bends at or near the middle and that, what seems to be a thin rod or lancet, comes from and is steadied by its tip. If we wait until the insect is fully gorged, we will see that as the puncturing structures are withdrawn the beak straightens and, when it is ready to fly, they have disappeared entirely within the covering structures. A mosquito has no mandibles or biting jaws, and no structures that correspond to them. The beak that is visible when the insect is examined is simply a cover or sheath for the real puncturing structures that lie within it. These puncturing structures when separated under the dissecting microscope, resolve themselves into a series of five or six very fine, slender rods; two on each side and one, somewhat more flattened and larger, in the center. This central piece is really a grooved or trough-like structure, covered by a thin, flat strip that makes the trough a tube. It is through this tube that the poison is

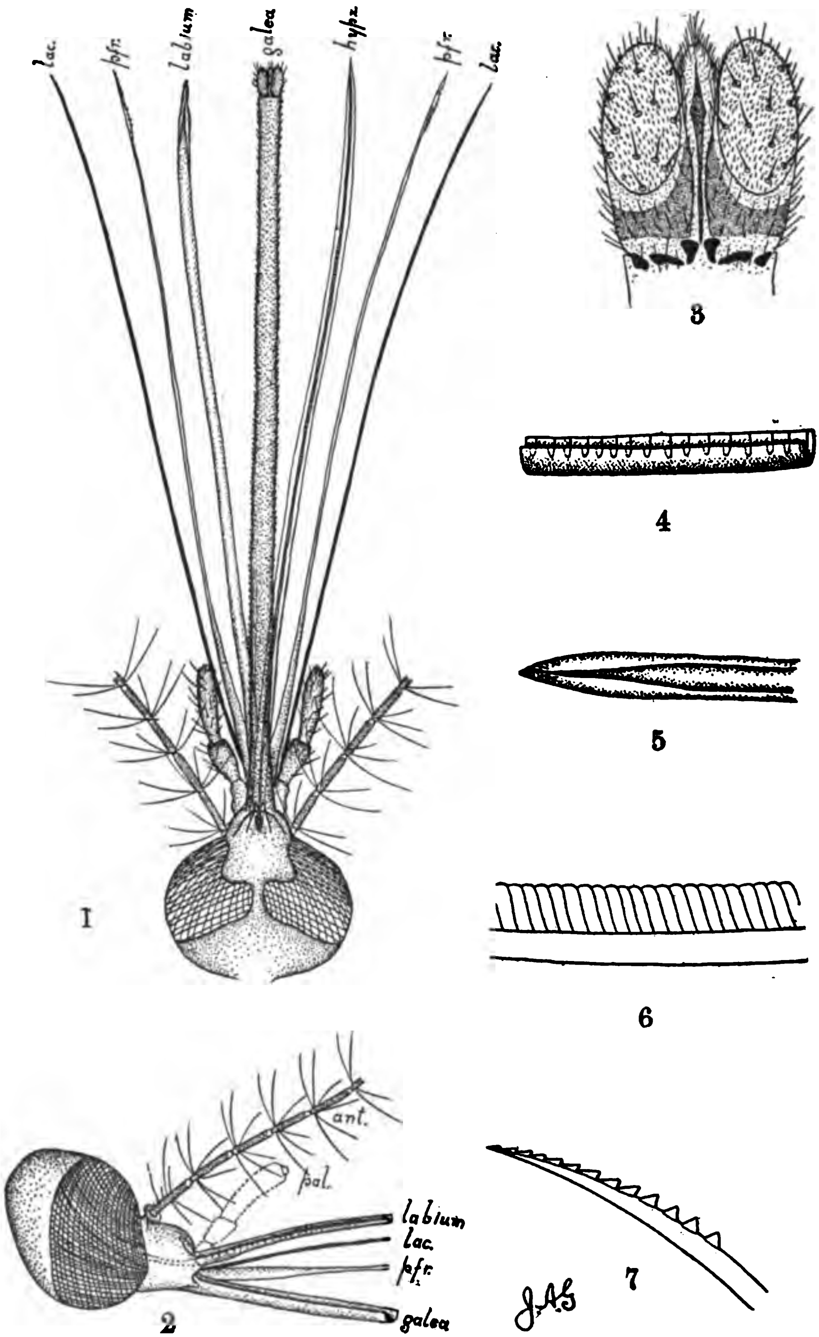

Figure 7.

Mouth structure of a mosquito (*Culex cantator*). 1, the head from below with mouth parts complete and named: the abbreviations are; *lac.* lacinia; *pfr.* palpifer; *hypx.* hypopharynx; 2, head from side; abbreviations are as above, and *ant.* antenna; *pal.* palpus; 3, tip of the galea or sheath; 4, a small part of the labium to show the trough-like structure; 5, tip of same; 6, small section of palpifer; 7, its tip to show the teeth. All figures enlarged: 3 to 7 much more than 1 and 2. (Original.)

introduced into the wound first, and the blood is sucked in afterward. If, as rarely happens, the covering strip is separated from the groove, six parts or lancets seem to be present. The usual appearance is five; the two central parts counting as one. The lateral lancets make two pairs, one of them very slender, except at the tip where there is a slight enlargement and a series of teeth; the other more flattened and blade-like with a lancet-like tip which may or may not have a slightly toothed edge. These lancets with the beak in which they run form the maxilla or second jaws of the insect and they are all connected at the base. They are purely surgical structures, meant for puncturing and cutting and have nothing to do with the actual feeding. The

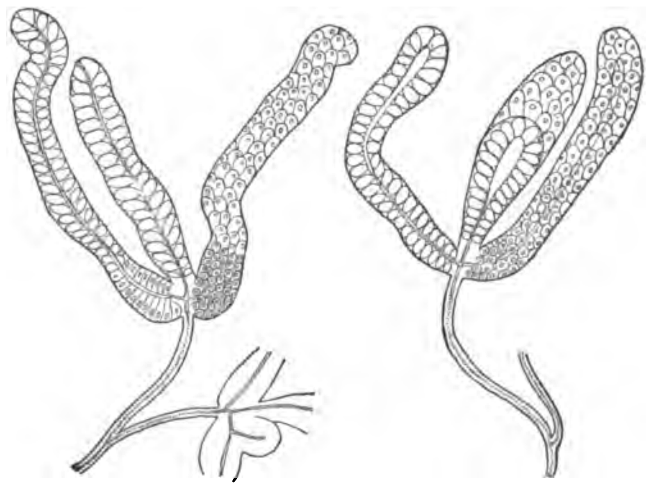

Figure 8.

Salivary glands of *Culex* at right, *Anopheles* at left; greatly enlarged. (From Howard's "Mosquitoes," by permission.)

central structures represent the labium or lower lip and they end at the base in the mentum which forms a sort of sucking pump leading into the œsophagus or throat. Just below the base, where the covering structure or epipharynx or palate takes its origin, the tube from the salivary glands has its opening. All of these structures in their proper relation to each other are shown at figure 7, in which each of the parts are named.

The salivary glands lie in the thorax just back of the neck and can be dissected out with infinite difficulty only. There is one set of glands on each side and these consist of a central part or bulb, which serves as a reservoir for the product or saliva and one or

two pairs of lateral structures, whose office is to elaborate or manufacture the material, which is stored in the central portion. From the base of this reservoir a fine tube or duct leads toward the head, within which it joins the similar tube of the other side, forming a larger tube for conveying the poison to the beginning of the epipharynx. When the insect attacks a victim all the piercing structures are forced into the skin as one mass and a droplet of saliva slides into the puncture almost as soon as it is made. The pumping operation begins immediately thereafter and may be observed as pulsations of the abdomen as it gradually fills with blood. It takes about three minutes for an insect to complete its meal and then it flies away, rests in some convenient spot until the blood is digested and is then ready for another attack.

BITE CURES.

All sorts of remedies for mosquito bites have been recommended, but nothing serves as well on the whole as the stronger water of ammonia. It may be applied undiluted or at half strength to the point of irritation. Preparations of cresol or carbolic acid, like phenol sodique or camphenol, are excellent, and in fact any astringent or soothing lotion will be of use. One of the simplest of the "old housewife's" remedies is the juice of an onion to be applied to the bite. There are others, varying in the degree of usefulness, but a list of these is scarcely needed. In those cases where there is much swelling or puffiness, a solution of baking soda forming a thin paste often gives great relief.

In any case scratching or otherwise irritating the bites should be avoided as much as possible.

POWERS OF FLIGHT.

It is easy to be mistaken concerning a mosquito's powers of flight, and the records as they stand are distinctly misleading. No mosquitoes fly during a high wind in the day time, nor during a very heavy wind, even in the evening. Most species, indeed, do not fly at all during the day, and only those species are troublesome that hide normally in the grass and are disturbed by walking through it. It is also true that mosquitoes keep down low and seek the sheltered spots when the winds are strong, even in the evening; but it is equally certain that some of them will get in at fourth and fifth story windows in cities. I have actually seen this and have received specimens collected as they came in by correspondents who made observations for me.

I rarely have *sollicitans* on the second story porch of my house, though the one below may be swarming; but occasionally some examples do get up. *Cantator* rises much more readily; but when there are many specimens I feel reasonably certain that *pipiens* is the offender. The principal flights begin just at dusk and become more marked until it is fully dark. On ordinary nights a falling off begins at about 9 oclock and few specimens are felt after 10. On sultry or very quiet nights the movement may last until midnight and there seems to be a somewhat less marked motion in the early morning. These facts have been noted by several of my correspondents as well, and Mr. Brakeley's observations have been especially full, because of his habit of sitting up until after midnight and making occasional trips outdoors to note conditions. Frequently he has found the insects in great quantities during the early evening and has stood for several minutes late at night in the same places without noting a single example. Yet on going outdoors just at or soon after sunrise, he has been met by specimens ready to attack.

As to actual powers of flight, the species, and even the sexes, differ. Males rarely fly except in very quiet evenings, and their flight is largely a hover, suitable for the mating, but not for great progress. Yet *cantator* males accompany the females for some distance inland: much further than male *sollicitans* ever does.

I have watched *sollicitans* carefully on many occasions and find that it flies quite readily against even a brisk wind and makes good progress. I have placed myself several times in an alley in the direct line of the wind, and have watched the insect come sailing against it without hesitation or apparent effort. I have driven at quite a rapid pace over infested roads and found that the specimens hovering over the horse and along the carriage had no difficulty in keeping up. I have been on a steam launch which was followed by a mosquito swarm more than five miles across an open stretch of water. The specimens were not in the launch for much of the time, because every effort was made to drive them out and keep them on the wing, which, as the boat was small, was an easy matter. Five or six miles an hour against an ordinary wind, or nearly double that when with a mild wind, I consider quite within the range of *sollicitans* or *cantator*.

Mr. Brakeley records a *perturbans* that was allowed to become blood filled and fly. It was during the early evening, quite light enough to follow the flight for a hundred feet or more, and the rate at which that space was covered by this fully fed female was a revelation! "At that gait she would make a mile in no time," was Mr. Brakeley's comment. It would be easy to detail obser-

vations made by others to the same effect; but it would add nothing to the force of the statements already made. Further evidence on the point comes under the heading of "Migrations."

MOSQUITO MIGRATIONS.

There is no point of greater importance established by this investigation than that certain species of mosquitoes migrate: i. e., they leave the places where they were born and come to maturity and fly long distances. Prior to 1902 the belief was that only in isolated instances, under exceptional conditions, did mosquitoes fly more than a short distance from the place where they became adult. Their radius of flight was expressed sometimes in feet, more rarely in yards, and almost never in fractions of a mile. Based upon that belief was the conclusion that mosquito control was purely a local matter and that almost any community could rid itself of trouble no matter what the surroundings might be; provided, of course, they were a reasonable distance away. No one fact in mosquito history impressed itself quite so firmly upon the mind of the public that looked into the matter at all, and the result was, in New Jersey, a series of local efforts in the most progressive communities. These communities did not take kindly to the suggestion when first made, that the bulk of their mosquito supply was not a local product, and some of them continued their hopeless task until the overwhelming swarms of 1903 and early 1904 seemed to prove all their previous efforts worthless and made them a laughing stock.

Yet the very earliest systematic collections demonstrated that certain species might be present in overwhelming numbers where no trace of their larvæ could be found. *Culex sollicitans* was the species that first attracted attention, partly because in my cranberry investigations in the pine regions it swarmed so numerously; partly because it was that year also the dominant species at New Brunswick. I have elsewhere spoken of my efforts to obtain eggs and larvæ of this species and my failure to find them inland, while at the shore every pool swarmed with them. My first shore collections were made at Anglesea, where *sollicitans* was at that time the dominant species. For that reason I did not find *cantator* and believed *sollicitans* the sole migrant. In 1902 Mr. Brehme took the field, Mr. Dickerson was detailed as opportunity served, and I devoted all available time to the same end. Never were marshes more thoroughly explored, and the result was that instead of one, we found four species breeding on them. Furthermore, we failed absolutely to find any of these larvæ

anywhere on the upland, though we found plenty of others. Except for *Culex salinarius,* the adults from these marsh wrigglers were found miles inland, infernal nuisances, where locals were almost or entirely absent.

In 1903, with additional funds, I had six men in the field and the voluntary assistance of Mr. Brakeley. Dr. Julius Nelson, Professor of Biology, engaged in oyster work along the shore, was also good enough to make certain observations for me, and the result was a complete demonstration of the migratory habits of *Culex sollicitans, C. cantator* and *C. tæniorhynchus.* The observations made during the early season of 1904, with fuller knowledge of the factors, were equally conclusive. The development of the broods on the Newark and Raritan marshes was watched almost from day to day. Before the larvæ matured, careful search was made for several miles back and along the first ridge of the Orange Mountains to make certain of what was developing there. The appearance of the adults was noted on the meadows, before a single specimen was seen in Newark. They were watched for a day or two slowly advancing until, a favorable night happening, the ever-increasing swarms arose and next morning had settled along the first ridge of the mountains. The second brood, maturing during the last days of June, was watched in the same way, and the early days of July, 1903, brought inland the greatest swarm of mosquitoes I have ever seen. They reached New Brunswick July 2d, and included the three species, *sollicitans, cantator* and *tæniorhynchus.* Meanwhile, Mr. Viereck was observing at Cape May, and watched the peninsula filling with *sollicitans* bred at the shore; not a larva of which he could find where the adults swarmed. He noted that after a continuous south wind the marshes became practically free from mosquitoes, and he noted further that a few days later blood-filled specimens with developing or developed ovaries returned to them from the upland. This seemed to him in the nature of a return migration for oviposition as all specimens were worn and battered.

From the Newark Marshes—using that term generally to include also all that section within the corporate limits of Elizabeth—the insects were traced to the second ridge of the Orange Mountains, to Paterson, to Morristown, and to Summit, in gradually decreasing numbers.

From the Raritan Marshes they were traced along the river to Bound Brook, to Somerville, to Dunellen and to Plainfield. Just how far inland this swarm penetrated I do not know.

Meanwhile Dr. Nelson was observing along the shores of Great Bay and the mouth of the Mullica River, finding little mosquito

trouble on the marsh until July 12th. On or about that day an extra high tide came over it, and on the 13th minute wrigglers were in every water-filled hole. Cold, wet weather retarded development, but on the 21st males were out in clouds and everything was in the pupal stage. On the morning of the 22d the females were out, but would not bite. On the evening of the 23d it was warm, with only a slight breeze, and the Doctor was brought from his hut by a peculiar humming noise which seemed to fill the air. He located its source at last between sixteen and twenty feet high above the marsh, where regular clouds of mosquitoes were hovering in their marriage flight. On the 24th few males were seen, but the females were in droves and as bloodthirsty as butchers. Then came cold west and north winds that kept the insects low down among the grass. On the 28th the wind veered to the south and continued all that night and all day on the 29th. On the morning of the 29th the number of mosquitoes on the marsh had diminished materially, and this was yet more decidedly marked on the morning of the 30th, when they were quite bearable. But in the woods where on the 20th there had been few mosquitoes they were worse on the 31st, when the Doctor came out to Tuckerton, than they were on the marsh itself.

Just after receiving this account from Dr. Nelson, I received a note from Mr. Brakeley, giving in detail a record of the arrival of *Culex sollicitans* in the pines, during the nights of July 28th and 29th, increasing during the successive nights to August 1st, when they were distributed everywhere in great numbers. Previously there had been practically none of this species, and the observed departure on the 28th and 29th from the marshes and the arrivals in great swarms over thirty miles away on the days immediately following, leaves no question as to the connection between the two. That the species could have bred locally is out of question, because the larval status of the pine region was thoroughly known.

In the Spring of 1904 weather conditions were unusually favorable for the development of a heavy brood of *cantator* along the entire coast north of the Great Bay. As early as March the larvæ were found everywhere, and on the Shrewsbury River marshes it was a race between the ditchers and the insects as to which should win out. A few cold days retarded the insects and gave the workers the chance of finishing the ditches that ran off full grown larvæ and pupæ by the millions into the maws of hungry "killies" that followed hard after the spades. The result was, no first brood on these meadows and the consequent exemption from mosquito attack of the entire surrounding territory!

On the Newark marshes the brood developed and early in May spread inland, covering a territory even greater than the broods of 1903, for now they were traced into the mountains north of Paterson and directly west to Bernardsville, where in ordinary seasons mosquitoes are practically unknown.

The Raritan River brood reached New Brunswick May 12th and the nights immediately following, and extended along the valley to Somerville, following essentially the same track as in 1903.

At Lahaway the first arrivals were noted May 17th, and by the 24th the Pines were filled with them.

For some reason no *sollicitans* developed on the Newark marshes up to the middle of July and not a specimen was seen or sent in by any correspondent from the towns where *cantator* swarmed. On the Raritan meadows one section developed a small brood in June, and this sent a few specimens to New Brunswick a few days thereafter.

South of Barnegat Bay *sollicitans* equaled *cantator,* but developed a little later, so that the first arrival reached Lahaway May 23d, and after a day of steady south wind and high temperature the morning of the 29th found them present in force.

Culex sylvestris, a breeder in fresh water swamps and marsh areas, also flies for some distance from its place of birth; but these flights can scarcely be considered migrations, and as its breeding places may be found almost everywhere, the species is really at home however far it travels. This feature also makes it difficult to determine the actual source of supply when the insect is troublesome.

Culex perturbans is almost certainly a true migrant, from Mr. Brakeley's notes; but as we are yet unfortunately ignorant of the early stages of this insect, this point cannot be considered proved.

Culex tæniorhynchus develops with *cantator* and *sollicitans* under the same conditions and migrates with them; but it does not fly so far and is always so much less abundant that it needs no especial account here.

One noteworthy peculiarity in all the salt marsh migrants is that the females are almost invariably sterile. I have examined hundreds of *sollicitans* from Lahaway, from New Lisbon, from New Brunswick, from the Orange Mountains and from numerous other points, and do not remember a single instance where a specimen had developed ovaries. In *cantator* occasional specimens with developed ovaries occur; but that is usually at points not very far from the marshes.

This fact points to the migration as due to a physiological cause. It is not merely a wind-driven lot of specimens unable to

maintain themselves, for in that case there would be a normal ovarian development. It seems rather as if the inability to reproduce resulted in a restless desire to wander. Just why so large a percentage of the females should be barren I do not know, nor can I see how this may be in any way of use to the species. It can scarcely be due to any lack of males, because when the species is bred in the laboratory both sexes develop in about equal numbers; the males usually a day or two before the females. So also on the marshes the grass about breeding pools may be full of males before a single female has developed. Nor is it possible that I have examined only fresh specimens in which eggs have not yet had time to develop. Mr. Viereck's observations indicate that *sollicitans* may oviposit a week after development to the adult stage, and my collections have extended over a period of more than a month from the same swarm. Furthermore, it is a fact that even in marsh collections only a small percentage of the females show developing ovaries. It is a fair statement from examinations made that in *sollicitans* not over 25 per cent. of the females are able to reproduce their kind. As to *cantator,* the percentage of barren females seems not nearly so great.

Prof. F. M. Webster, of Urbana, Ill., recently published concerning the flights of the Buffalo gnat, and records among other things that he found all the migratory forms barren. As the mosquito and the Buffalo gnat are members of the same order and not too distantly related this record forms an interesting supplement to my observations and indicates that among the flies there is some correlation between a migratory habit and the inability to reproduce.

Meanwhile it is certain that the migratory species dominate a large section of New Jersey, and make their control a State rather than a local problem.

The question has been asked whether, assuming that New Jersey actually controlled her own output, she would not suffer from swarms bred beyond her jurisdiction. The answer to that is yes, as to one point only. The marshes on Staten Island, opposite the Elizabeth River, are as bad as anything within the jurisdiction of our State, and until these marshes are treated, the city of Elizabeth will never be free from mosquitoes. Rahway is threatened to a less extent; but at no other point is there danger of any incoming supply from points beyond the State line.

Delaware Bay is too broad for ordinary mosquito flights over water, and their tendency is not in that direction as a rule. The marsh area along the coast of Delaware is narrow and as the

Delaware River narrows the banks become higher and the water less salt. As soon as it becomes fresh the migratory forms are unable to breed along its banks. The danger from the west bank of this river may be considered as naught. The banks of the Hudson are high above Manhattan and nowhere along its shores is there any marsh area that is dangerous to New Jersey. Long Island has extensive marsh areas, breeding great numbers of mosquitoes, but Staten Island and Manhattan act as protectors to the New Jersey shore, aside from the fact that active work to control the insects is in progress there.

What directs the flight of mosquitoes or determines the direction in which they go? Primarily, the wind. A soft warm south wind will carry them for miles in a single night, and on a quiet night they will fly inland for long distances even against a light breeze.

A warm west wind carries swarms out to sea, where they perish. Such swarms have been recorded fifteen miles out, and are common five miles out. Nevertheless, though these sea flights are well authenticated, they are not usual, and the chill air at the water's edge seems to invite a settling. This I have observed on Five-Mile Beach, where on a west wind, which carried the insects from the marsh area, they seemed checked as soon as they reached the beach, and descended in great numbers to such shelter as was afforded by the scant beach grass and even the wash-up material at the high-tide line. Normal flights are always inland when there is either none or a favoring wind. Seaward flights are forced when high temperature and a stiff west wind work together, as they do but rarely.

COLOR PREFERENCES.

It has been asserted that certain colors will attract and others will repel mosquitoes; but no very definite experiments have been recorded, so far as I know. Dr. Johnson during his work in 1902, lined the back of the box in which he kept his mosquitoes under observation, with paper of different colors; but he seemed to find no evidence of any very marked preference.

In the field I have noticed that black clothing was uniformly more attractive to *sollicitans*. A man with a black alapaca coat and black hat would have mosquitoes all over the back, while another walking with him, clothed in a gray coat and straw hat, was almost exempt. So, when standing in grass sheltering *sollicitans,* the insects began crawling upon the dark pantaloons in much greater numbers than on gray or light brown. I have no suggestions to make as to the reasons for this preference; but it

Figure 9.

Shows Castor Bean plants at Porch corner and in plot just opposite. (Original.)

undoubtedly exists in *sollicitans* at least. I have not observed it in others.

VEGETATION AND MOSQUITOES.

From the fact that mosquitoes are often found in large numbers in grasses and bushes, and are usually most troublesome about porches that are vine-covered, a popular belief has developed that this vegetation in some way favors their breeding or that they actually breed in the grass itself.

That they breed in or among the grasses and bushes is of course an erroneous belief; but there is no doubt that such places afford convenient shelter for the insects and that they rest there during the day. Those that hide in the grass are usually the salt marsh species; those that seek the shelter of bushes and vines are usually *Culex pipiens* and *restuans,* the species of *Anopheles* and sometimes, *C. sylvestris.*

The better the hiding places, and the nearer they are to the house, the more its inhabitants are apt to be troubled. Other than as above stated there is no relation between the two.

Coming somewhat under the same heading are the suggestions that certain plants are so repugnant to mosquitoes that they will not go near them and that these might be employed as repellants.

Castor beans were once suggested and as I had usually set a few of these very ornamental plants, I put out several groups of them in 1902 in my front lawn and next to the porch. They were faithfully tested; but under the very plants themselves the mosquitoes were a little worse than anywhere else. The offenders were *sollicitans* and *cantator* and for these at least the castor oil bean has no terrors. Mr. Brakeley had an almost identical experience with the South American castor bean seeds which he procured to test this point.

No other plant has been tested by me and none of the reports concerning other plants have been sufficiently definite to make experiments advisable for the present investigation.

MOSQUITO WEATHER.

That the character of the weather is in some direct relation to the prevalence of mosquitoes is recognized by the common reference of a sultry, rainy period in mid-summer, as "good mosquito weather." What has been already said of the breeding habits of the insects explains why that should be so. Water is needed for the wrigglers; a heavy shower produces puddles and pools,

often of considerable extent. When the air is full of moisture, evaporation is slow and an occasional shower, even if light, serves to keep up the supply. The heat favors the development of the micro-organisms in the water, the wrigglers that will be found in the pools within forty-eight hours after their formation have an abundance of food, and in six to eight days from the egg, adults appear. This applies to all kinds of mosquitoes, whether inland or on the salt marsh, and a spell of such weather may produce a brood of the marsh species where no tide has covered the meadows for weeks. Clear, drying weather always checks development even if there be no actual drought. So there might easily be a season with plenty of rain, yet not well adapted for mosquito breeding. On the other hand, no matter how dry the weather, a high tide on the salt marsh may start the development of a brood; though in that case many of the shallow areas would dry out before the larvæ coud reach maturity. At some points along shore "mosquito weather" is caused by specific winds and the occurrence of the insects on these winds is due simply to the favoring conditions for flights from the salt marsh. Few insects are so dependent upon weather conditions as the mosquito and yet fewer can take advantage of favorable conditions so readily.

CHAPTER IV.

HOW MOSQUITOES DEVELOP.

THE LIFE OF A MOSQUITO.

How long does a mosquito live? It is a simple question, not easily answered, because the answer cannot be the same for all the species. We know in general that the life of the male is short, limited to a few days or until he has fulfilled his function in life by impregnating the female.

As to the females we know that some species hibernate, i. e., live through the winter as adults, and we know that some of them begin to seek quarters during the latter half of September. We know also that there is no general exodus from hibernating places until May and for such species there is a life of at least seven and probably more nearly eight months. We have rather assumed that in summer the length of life was determined, some-

what, by the opportunity for oviposition and that, when eggs are laid the insect's mission in life is over and it dies. In a general way I believe this to be correct; but we have learnt now, that mosquitoes may bite even after all the eggs have been laid and it is by no means certain that all species will seize the first opportunity to lay eggs. We have kept specimens in captivity for two months, feeding them on fruit juices and even on blood; but we have believed that these were abnormal conditions which would not hold in the open air. I had determined by observations in 1903 that for the migrants at least, there was no shorter life than from four to six weeks and that, as they had no eggs to deposit, there was no particular period when their life work might be said to be accomplished.

It is difficult under ordinary conditions to measure the life period from out-door observations, for one brood usually comes before the last of the other is gone, and in the overlapping there is no means of knowing whether there are old or new specimens under observation. The mosquito cage experiments on the Newark marshes in 1903 were meant to shed some light upon this subject, and so they did; but they gave only the data for life length on the marshes and not for the forms that fly inland.

Mr. Brakeley's notes on *Culex aurifer,* when carefully collated, proved for that species an adult life of three months at least, from the beginning of May when the last larvæ were observed, to the end of July when the adults yet occurred in bloodthirsty swarms. Now *aurifer* is no migrant and, so far as we know there is absolutely no reason why it should not oviposit where the future brood is to be developed.

The summer of 1904 was remarkably favorable for practical observations on this point. On all the marshes a heavy brood developed in April and traveled inland during the early days of May. On the Newark marsh the ditching work completely annihilated the second brood due about July 4th; but on the Elizabeth and Raritan marshes that brood developed. On the Elizabeth marsh the brood was cut short by drought but sent a delegation of the survivors into the city. But there was no migration to Newark and none to the Oranges or points north, that are usually supplied from Newark. The brood on the Raritan marshes was completely absorbed before it reached New Brunswick. It was small at best and consisted largely of *sollicitans,* not one of which reached my city. *Cantator* covered Newark during the first week in May and reached Montclair and South Orange about the same time; but though I am certain that no new migrants reached these points, practically all the specimens I received from general collections were *cantator* up to

the end of July. At New Brunswick, where the conditions were under my own observation, *cantator* arriving May 12, yet lingered August 1st.

The term lingered is advisedly used because before the middle of July the city was practically free; but on the outskirts and in the gardens, where, as in my own, there were excellent hiding places where the specimens found shelter during the day and invaded the porches at night, the supply seemed undiminished. So in Newark it was only from the gardens that any number of specimens came, while the town itself, which had been covered in May, was practically free in early July; before the end of the month the Jersey City and Elizabeth marshes had sent in a new supply.

It is fair, under conditions as observed, to give the migratory forms inland, an active period of nearly or quite three months. The importance of dealing with the early mosquito broods is especially emphasized by these observations, for when a place is once thoroughly seeded down, it takes a long time to work out the pest.

Newark's experience proves one side of this proposition; the first brood was allowed to develop, but though the drainage work cleaned up the second and later broods, specimens of the first brood lingered until after August 1st. The experience of Monmouth Beach is on the other side; the work done there got ahead of the first brood and, as a result, there were practically no mosquitoes at all, while the other shore communities were suffering.

In 1903 the second brood, developing in June and on the wing in early July, supplemented the left-overs of the May migration and gave the appearance of a "double infection"—as it really was—which lasted until September.

Anopheles has not been as closely observed because this is a continuous breeder; larvæ of all sizes being constantly found in the same pools. It is more than probable, however, that the life period is not less than that of the species of *Culex*, and one month for the individual is certainly a conservative estimate. It is probably longer; but even one month is amply sufficient to provide for the development of the malarial parasite and the transference of the disease.

BREEDING PLACES.

It is a popular belief, which has been already referred to, that mosquitoes develop in the grasses and shrubbery in which they are so frequently found; but that is a mistake, for no species

Figure 10.

An Experiment Cage on the Newark meadows: size 8 x 8 x 8 feet. (Original.)

known to us at present can breed except in water. It need not be clean water and there need not be much of it; but water there must be in which the wrigglers or larvæ can feed and grow, They are built for an aquatic life and for eating the micro-organisms that live in water. On land they are absolutely helpless, without power of motion and without the ability to take food.

Without water, therefore, there can be no development of mosquito larvæ, and it is matter of the utmost importance to determine under just what circumstances a body of water becomes dangerous as a mosquito breeder and what waters are safe.

In the first place, large ponds or open permanent pools are safe except at the edges, because mosquito larvæ will not breed where the water is disturbed by the wind, forming waves or ripples. If the pond or pool is inhabited by fish other than those that live on the bottom or in the mud, no larvæ can maintain themselves except in shallow, grassy borders where fish cannot penetrate. Any permanent pond or pool can be made mosquito safe by cleaning up the edges and stocking with fish. As to the kinds of fish, that is discussed under another heading. Every fountain or artificial water basin, no matter how small, should be stocked, if only with gold fish, and it goes without saying that this applies to larger bodies as well. Any area of shallow, stagnant water sheltered from the wind and without fish may become dangerous from the mosquito breeding standpoint, whether large or small. Along the grassy edges of ponds not otherwise dangerous, *Anopheles* find convenient places for developing.

Running streams are usually safe except in the quiet eddies, where *Anopheles* loves to hide close to the banks. There are also a few *territans* bred in such places; but not many. Almost any of the minnows or sunfish that usually inhabit such streams will serve to keep them clean, except where the edges are shallow and grassy; but here other larvæ and aquatic insects generally tend to keep them down. As a rule, larger streams in rocky or gravelly bottoms are entirely safe. Sluggish streams in open meadow land over a mud bottom are likely to be more or less troublesome.

Pools covered with duckweed are not mosquito breeders whenever the weed covers most or all of the surface. The plant forms so complete a cover that the mosquito larvæ cannot reach the surface, hence choke to death. Such pools also are the favorite habitation of many aquatic insects. So pools that are filled with the green, slimy and stringy *Spirogyra* contain no wrigglers, because the latter become entangled in the vegetable threads and die. In fact, the mere presence of a small quantity in a breeding jar seems to act almost as a poison to the larvæ.

Dark, woodland swamps breed few mosquitoes of any kind, and such as do occur there are not troublesome and do not get away from their dark haunts. Very few wrigglers of any kind are found in sphagnum swamps, open or overgrown, and none that do occur there are at all troublesome.

Areas densely overgrown by cattails are safe as mosquito breeders, contrary to general belief. The hundreds of acres of such area in the Hackensack Valley do not furnish any of the supply for the neighboring towns. I have been over such swamps many times and my assistants have spent days in searching through them. Adult mosquitoes were often plentiful enough, but their larvæ were never found.

Salt ponds, large or small, on the marshes are always safe, because they almost always have perpendicular banks and are stocked with fish and other marine life at every tide that fills them. So a marsh that is covered at ordinary high tides can never breed mosquitoes. Nor can a flat marsh area with scant vegetation, from which the water drains completely, become a source of danger. Where fiddler crabs occur in numbers over a stretch of marsh land their holes drain it so completely that wrigglers have no chance. More than half of the entire marsh area along the New Jersey coast comes under the "safe" heading and breeds no mosquitoes of any kind.

Any pool or puddle of water, no matter how produced, in a road, a ditch or gutter, a depression in a city lot or a low meadow, that holds water for a week, may and usually does breed mosquitoes. A half filled pail, or tub, a horse trough, even an iron bucket or tin can that holds water will be apt to have a wriggler population, and the species will be usually *pipiens* or *restuans,* with a sprinkling of *Anopheles.* In cities, and especially in the smaller, incompletely sewered cities and in the outskirts, neglected gutters taking house waste or forming pockets that hold water are good sources of local supply. Sewer catch basins are very often good breeders and so are cesspools and pits for liquid manure. Water barrels have an established reputation in this line, and so have shallow cisterns. In fact there is no pool or body of water so small or so foul as not to breed the common house mosquitoes, and this may be indoors as well as out.

An open swamp area, broken by hummocks of grass and partly filled with reeds, rushes, spatterdock and lily pads, with shallow, overgrown edges, offers ideal conditions for *Anopheles,* because these may find shelter among the vegetation even if fish are present. Wooded swamp areas like the Great Piece Meadows and other similar stretches along the Passaic, have numerous pools so situated as to form ideal breeding places for *Culex sylvestris.*

In fact it is in the pools of low, swampy regions generally that this species finds its favorite habitation. It is the only inland species that has any reputation as a migrant and hence it is of more than local importance.

There are low places in every woods, and in New Jersey we have considerable areas of low, swampy woodland which are full of water during the winter: in these great numbers of wrigglers develop in early spring, and in some at intervals throughout the summer. Fortunately the species that breed here are local in their habits, and do not usually get out of the territory where they were born. It is almost safe to count on finding mosquito larvæ at any time during the summer in a woodland pool.

As to the salt marshes, there are areas, usually near the edge of the highland, that are rotten or full of holes and irregular depressions, and in every one of these larvæ develop when they become filled by either rain or tides. There are also larger depressed areas, reached only by the highest tides, which are refilled chiefly by heavy rains during the summer, and these are among the heaviest of all breeders because of their extent. There is a certain relation between the character of the vegetation and the prevalence of mosquito breeding places, and that has been worked out by Mr. Viereck, whose account may be given.

Mr. Viereck's Report.

"At the seashore and inland, high and lowland are characterized by species of grasses and sedges which grow only either in moist or dry places. Thus, inland, while no breeding was discovered in Sphagnum swamps, the worst breeding areas for *Culex sylvestris* were found in depressions where the sedge of the genus *Cyperus* grows. This sedge grows chiefly in places where the ground is low and prone to hold rain-waters.

"At the shore where the highland joins the low sedge marsh there is a zone of (commonly called) salt hay composed of at least three prominent genera of grasses. Nearest the highland and in the less black soil is the three-square grass, *Scirpus;* this does not harbor mosquito-breeding depressions ordinarily, although in some cases, especially near the shore, it grows with *Cyperus* in low, dangerous places. Beyond the three-square grass, and really a continuation of it, is the black grass, *Juncus,* which constitutes the largest percentage of salt hay and harbors the worst breeding places of *sollicitans* and *tæniorhynchus* (as well as *cantator*). Quite often the standing water causes the grass to drop off, leaving only a stubble behind to stay in the dark brown area, which is a chronic mosquito pond, delivering a brood after every rain which adds enough water to last a week. Where the black grass grows close together breeding is impeded.

"Between the black grass and the sedge is the joint-grass, *Distichlis,* which grows by runners and leaves many spaces between the stems, where mosquitoes breed quite freely. In this grass all the salt marsh species proper, and even *Anopheles,* will readily evade fishes, though it admits fish better than the black grass.

"Beyond the joint grass the sedge, *Spartina,* is usually well drained naturally. Where this natural drainage is cut off by man or by nature (the latter

appearing to be rarely the case), the sedge march becomes just as virulent as black grass, and is also reduced to a stubble in chronic areas.

"The genera of grasses here named do in a general way hold to their respective territory; though one invades the other's ground quite frequently.

"Cat-tail, *Typha*, grows in fresh water and fills in thoroughfares, etc., when cut off from the sea. If it be filled with rain-water, such a cat-tail marsh is made dangerous by interrupted drainage, though inland it seems to be quite free from mosquito breeding. The marsh-mallow, *Hibiscus*, grows also in places prone to breed mosquitoes.

"Taking into consideration the flora, the most serious breeding places can be located as well in dry as in wet weather.

"The salt hay zone extends along the edge of the highland everywhere along the coast. Where grading has been done the remaining depressions, filled with salt hay, can be readily recognized, and will breed all the marsh species."

Not least among the breeding places are those created by man's interference with natural drainage. I know of numerous cases where streets, roads or avenues have been built through a safe, well-drained area without regard to existing conditions, leaving as the result on one side of the road a stagnant swamp area, without outlet for surface waters, which was bound to and did grow up into a veritable paradise for *Culex pipiens* and its allies, as well as *Anopheles*. Only a little consideration by the engineers in charge would have prevented all this without much if any additional cost. This sort of artificially created breeding place is by no means peculiar to New Jersey, and affords an illustration of the fact that results aimed at may be obtained with the addition of results not contemplated or desired.

Railroads are great offenders in this direction. Their aim is, usually, to get a road-bed at the least possible cost and drained so as to leave a dry surface as far as possible out of reach of storm effects. When on a comparatively level stretch or in a cutting, the road-bed is usually a little higher than the regular surface level and a shallow ditch takes the surface water from the railroad track level. What becomes of the water after it gets into this ditch is not considered unless the quantity endangers the road. It may and often does lie for days and weeks, affording ideal conditions for several species of *Culex* and the common species of *Anopheles*.

In fact, there is scarcely a railroad ditch draining a road-bed that does not breed mosquitoes, and in at least half the cases there is no real necessity for allowing the water to stagnate at all. It could have been disposed of by the engineer from the beginning if the desirability of doing so had occurred to him. There are numerous cases in the State where parallel roads leave a depression between their rights of way from which water is rarely absent and where mosquito breeding goes on unchecked. The same disregard of natural drainage when road-beds are run through a low or swampy area that characterizes the usual road

Figure 11.

The upper figure represents a typical lot breeding pool from which thousands of mosquitoes emerge; the lower figure shows a neglected gutter, weedy and with stagnant pools. (Original.)

Figure 12.

Typical wood-land swamp area. The water has been treated with Phinotas oil and appears milky white. (Original.)

builder, is found in the railroad engineer. I have in mind a swamp area in Camden County, where a Y turn-out left a depressed triangle of swampy area an acre or more in extent which is now one of the most virulent breeders imaginable. An eight-inch pipe put down when the dams were built would have avoided all trouble at a slight expense. It will cost dollars now to effect a cure, where cents would have served to prevent trouble.

Railroad ditches and drainage must be looked after then, and in most cases a very simple bit of filling or clearing out will be all that is necessary. I have always found railroad officials very ready to co-operate in the work against mosquitoes, and believe that any unsafe place on their land will be readily filled from the nearest possible source as soon as their attention is properly called to it.

FOOD OF MOSQUITO LARVÆ.

The question, what good are mosquitoes anyway?—assuming that everything is of some use—is usually answered by the statement that mosquito larvæ purify the water in which they live by eating the micro-organisms that would otherwise render it foul. In that way they would become of value as scavengers and would be entitled to consideration; assuming that the premises are correct. We would have to count out those species, however, that live only in clean water, and it would require proof that some of the foul water in which wrigglers are found was really improved to an appreciable extent. It would also have to be demonstrated that the temperory and other pools in which mosquito larvæ breed were really of some advantage; for to raise mosquitoes to keep unnecessary and undesirable pools clean would seem to be not quite in accord with modern ideas of the fitness of things. Finally, it would also require proof that the purification of such pools, assuming them to be desirable, could not be obtained in some less irritating manner.

It becomes a matter of interest, therefore, to know exactly concerning the food of the wrigglers and to determine this, as well as to seek a reason why certain species breed on the salt marshes only, Mr. Horatio N. Parker, Health Officer of Montclair, New Jersey, was invited to study the question from material to be supplied by the office.

Dr. L. O. Howard in his comprehensive little book on mosquitoes speaks specifically of the food of *Anopheles* larvæ only, and what he says is worth quoting: "As already indicated, the principal food of the larvæ of Anopheles seems to be the spores of algæ; but, as we have pointed out, they will swallow anything

which floats on the surface of the water. I have seen one nearly choke to death in the attempt to swallow a good-sized bit. The English observer, Dr. Daniels, in the course of his investigations in Africa found that the contents of the intestines of the larvæ are mainly vegetable matter—in some cases entirely so. Occasionally limbs of minute insects or crustaceans were found, as well as scales of mosquitoes and insects. 'On watching them feeding it is seen that all minute particles are drawn to the mouth; but many of them are rejected. This rejection is somewhat arbitrary, as a particle at first rejected is often subsequently swallowed. Among the bodies seen to be swallowed I have seen living minute crustaceans and young larvæ both of Anopheles and Culices, but as a rule living animals either escape or are rejected.' Christophers and Stephens state that in their observations in Sierra Leone the food of the majority of the Anopheles larvæ seemed to be a unicellular protococcus."

Elsewhere Dr. Howard states that "The larvæ feed either at the surface or below the surface and their food is composed of all sorts of floating particles, and in the case of the larger forms they may even bite aquatic vegetation."

Mr. Parker's formal report explains itself, so far as it goes:

Report on the Food of Mosquito Larvæ.

BY HORATIO N. PARKER.

Professor John B. Smith, State Entomologist, New Brunswick, N. J.:

DEAR SIR—Herewith I present the results of my investigations of the food of mosquito larvæ. The specimens examined include several species and were collected from seven cities in different parts of the State. Also samples of mud from marshes where mosquitoes breed were analyzed.

The method of examination was to carefully clean the larvæ and then extract the alimentary canal, which was crushed and examined microscopically. Most of the specimens were sent to my laboratory in the water in which they were collected and these were most readily examined; but a few specimens were preserved in alcohol. This method of preservation was not satisfactory.

I find that algæ of different kinds form the chief food of the larvæ, and that in examinations of this kind the diatoms are present more frequently than other forms; however, we must not be hasty to conclude that they form a preponderance of the food supply, for they have hard silicious shells, which are not macerated by the larvæ as is the rest of the food.

In some of the specimens protozoa were found, and as most of these animals are very delicate, the chance of discovering them in the alimentary canal of the larva is very small indeed. So the protozoa may form a more important part of the food of the larvæ than appears from my examinations. In my analysis appears the term "Amorphous matter," which is used to designate matter which is plainly of organic origin, but is too thoroughly disintegrated to be identified.

It is well known that the larvæ have the habit of mulling sand-grains, and these were commonly found to form a part of the contents of the food canal. It is impossible to say whether the mosquitoes mouth the grains merely be-

cause they chance to lay hold of them, or whether they are covered with a thin organic film which serves the larvæ as food.

I conclude from my studies that the mosquito larvæ seize and eat all small particles that come in their way, and that to some extent from these particles themselves, though mostly through vegetable and animal forms growing attached thereto, they derive their chief sustenance. I am also of the belief that there is no hope of exterminating the mosquitoes by attempting to destroy their food supply, for while it may be possible that some breeding places may be so rich in food material as to foster growth of larvæ to a greater extent than others, it is certain that practically all breeding places furnish enough food to support myriads of mosquito larvæ.

The plants and animals which form such an important part of the food supply of the larvæ are so small that a microscope is required either to discover them or make out the details of their structure. They live in fresh water and form a part of the lower orders of the vegetable and animal kingdoms. The plants being grouped among the algæ and the animals among the protozoa.

Among the algæ are distinguished these three classes: the diatoms, green algæ, and the blue-green algæ.

The diatoms are little unicellular, flowerless plants, which grow wherever there is moisture. They can be distinguished by the naked eye, and they form the brown slime that accumulates on the bottom of pools and on the stones, sticks and grass that are in them. The diatoms have hard, quartz-like shells of beautiful, graceful shapes, which are covered with delicate markings. From their form the diatoms take their names, such as *Navicula* (little boat), *Asterionella* (little star), etc. The two other classes of algæ form the pond scums, which in the mass are somewhat repulsive to the sight and which many uninformed people regard as unhealthy. In reality they are to some extent purifying agents in the water in which they grow, and when looked at under the microscope are very beautiful.

The protozoa are microscopic, unicellular animals which, as a rule, lead active lives in the waters in which they grow; but there are a few forms which remain attached to lilies, sticks, grass, etc., which are found in the water. These forms are the ones most usually consumed by the mosquito larvæ, and possibly form a considerable part of their food supply; however, they are so delicate and easily destroyed that there is very little chance of identifying them after they are once inside the larva.

Besides these things are the bits of fibre which are stripped by the mosquito from the grass and other coarse plants that grow in the water. The mud that I examined from certain salt marshes where mosquitoes breed proved to be highly organic, but there appeared to be nothing in it peculiarly adapted for larval food. However, the texture of this mud is such that it will retain moisture for a long time, and it may be that for this reason the mosquito deposits her eggs in it.

Below I append the analyses of the contents of the alimentary canals of certain larvæ:

Culex pipiens—Larva from Metuchen, N. J.; collected the 26th of May, 1903; examined the 7th of June, 1903. Larva No. 1, Sand-grains, Amorphous matter, Insect scales; larva No. 2, Sand-grains, Amorphous matter, Insect scales, Melosira.

Culex sollicitans—Salt pond, Cape May, N. J.; examined June 7th, 1903. Larva No. 1, almost wholly minute Naviculæ; larva No. 2, the same.

Sayreville—Examined on the 7th of June. Larva No. 1, Amorphous matter, Sand-grains, Oscillaria; larva No. 2, Sand-grains, Oscillaria, Navicula, Cyclotella, Insect scales, Amorphous matter.

Sandy Hook—Examined 7th of June. Pupa:—Protococcus.

Source unknown—Examined 7th of June, 1903. Larva No. 1, Navicula, Cyclotella, Oscillaria, Amorphous matter; larva No. 2, Navicula, Synedra Oscillaria, Amorphous matter, Sand-grains.

Source unknown—Bottle had been standing in the laboratory some time; had dead Culex in it; examined 8th of June. Larva No. 1, Melosira, Oscillaria, Closterium, Sand-grains, Vegetable fibres, many Culex scales.

Beach Haven—Collected on the 11th of June, 1903; examined on the 18th of June. Larva No. 1, Navicula Vegetable fibre, Amorphous matter; larva No. 2, Navicula, Cyclotella, Protococcus, Vegetable fibre; larva No. 3, Navicula, Insect scales, Vegetable fibres.

Culex pipiens—Collected from Jersey City; no date; preserved in alcohol. Larva No. 1, Synedra (many), Navicula (many), Surirella, Protococcus, Conferva, Oscillaria, Cosmarium; larva No. 2, Synedra (many), Navicula (many), Cyclotella, Protococcus, Cosmarium, Vegetable fibre.

Morristown, N. J.—Collected on the 17th of June and examined on the 23d of June, 1903. Larva No. 1, Surirella, Navicula, Insect scales, Vegetable fibres (many); larva No. 2, Epistylis, Euglena, Arcella, Navicula, Vegetable fibre; larva No. 3, Arcella, Epistylis, Navicula, Synedra, Insect scales, Vegetable fibre.

Collected on the 2d of July and examined the 8th of July. Collected in pails from New Brunswick. Preserved in alcohol. Examination of several larvæ showed that the chief food was a filamentous alga of some kind, with a few Difflugia and diatoms.

Culex territans—Sample from the east side of Raritan river, New Brunswick. Collected the 7th of July and examined on the 18th of July. Larva No. 1, Pinnularia, Stauroneis, Pleurosigma, Phacus, Debris of filamentous algæ; larva No. 2, Pinnularia, Navicula, Staureneis, Debris of filamentous algæ.

Anopheles punctipennis—Sample from New Brunswick, N. J. Larva No. 1, Eunotia, Oscillaria, Closterium, Navicula, Conferva, Gomphonema, Synedra, Scenedesmus, Docidium, Botryococcus, Insect scales, Vegetable matter; larva No. 2, Cosmarium, Synedra, Pinnularia, Conferva, Raphidium, Closterium, Sand-grains.

C. territans—Larvæ were examined and found to contain nothing but a filamentous alga of some sort, probably Conferva. Larvæ from Sicard and Morrell streets, New Brunswick, had developed into pupæ when received, so the results were part inductive; but their food was entirely vegetable. A sample of red mud from Richardson street gutter, New Brunswick, was swarming with bacteria and a ciliated protozoan of some sort. There were no diatoms or algæ.

Culex pungens—From New Brunswick. Fed almost wholly on the minute ciliated infusorian of a green color. Species not determined.

Anopheles punctipennis—Larva No. 1, Ciliated green infusorian, Cyclotella, Conferva, Scenedesmus.

Culex pungens—Larva No. 2, Ciliated green infusorian, Pleurosigma, Scenedesmus, Raphidium, Pediastrium.

Respectfully submitted,

HORATIO N. PARKER.

In addition to this formal report Mr. Parker's letters contain reports on special lots sent him from time to time, and occasional remarks of interest and value.

Under date of June 24th, commenting on the specimens from Morristown, he says: "This is a very interesting lot, for in *Epistylis Arcella* and *Euglena* we have animal food. I have been expecting that the Protozoa are utilized by the mosquito larvæ for food and I am glad to find a demonstration of my suspicions.

"Of course this animal food is much more perishable than the vegetable, so that we may be giving undue weight to the proportion of vegetable food in the intestine. I do not think we could find the Protozoa in preserved specimens so that I am

Figure 13.

A salt marsh breeding area caused by building a road which cut the natural drainage. (Original.)

more convinced than ever that the best way to ship specimens is in the water in which they are taken."

August 14th, he writes: "It would be an interesting thing to know whether the mosquito larva mouths the sand grains because of the bacterial phytoglea that covers them or because of the diatoms that may be attached or because it does not know any more than to mull everything that comes in its way.

"It seems to me that this question of the food of mosquito larvæ is very obscure. We simply know that in examining the contents of their alimentary canals we find somewhat constantly, certain rather gross objects. We do not know whether they are the true food of the mosquito or whether they only happen to be taken in by accident in the course of feeding by the insects.

"Can the larvæ live on bacteria or on any other one thing alone? It seems to me this might be determined by patient experimenting."

Early in September larvæ of *Culex sylvestris* from the Passaic Valley swamps were sent in and reported upon as follows:

"I examined the *sylvestris* larvæ which you sent me and found that their food consisted for the most part of Conferva. Below I give the analysis of one larva which is typical of the lot:

"Larva 1: Synedra; Navicula; Conferva; Phacus; Pinnularia."

Larvæ of *Culex salinarius* and *Anopheles crucians* were sent in and reported upon September 14th as follows:

"The *C. nigritulus* (*salinarius*) larvæ arrived here from Cape May in good condition, but they were destroyed by the larva of some sort of a water beetle which was in the bottle and which I did not notice until the following morning. The *Anopheles* from Cape May (*crucians*) were examined and the principal articles of food were found to be Phacus and diatoms. I give below the analysis of two of them which are typical of the lot:

"Larva 1: Protococcus; Scenedesmus; Cymbella; Navicula; Pediastrum; Cosmarium; Phacus; Synedra; Cyclotella. Larva 2: Phacus; Cymbella; Cosmarium; Scenedesmus; Synedra; Pediastrum; Cyclotella."

September 16th, the following report was received: 'This morning I received a sample of *Culex nigritulus* (*salinarius*) larvæ marked Matawan, September 12th. Their food is almost wholly diatoms, although there was also found vegetable fiber, remnants of green Algæ and evidences of an infusorian of some sort. I give, below, the analysis of two larvæ:

"Larva 1: Synedra; Navicula; Pleurosigma. Larva 2: Navicula; Synedra; Pleurosigma; Difflugia; Raphidium; Vegetable fiber."

These studies by Mr. Parker add materially to our definite knowledge of the food of mosquito larvæ, and do not bear out the idea that the wrigglers are of material aid in purifying water. Nevertheless, as Mr. Parker suggests, many organisms would leave no trace in the stomach soon after digestion and the only way to determine whether the larvæ can actually subsist on bacteria and similar organisms is by direct experiment, placing carefully washed larvæ in a diluted culture of the organisms it is desired to test.

CHAPTER V.

HIBERNATION OF MOSQUITOES.

Mosquitoes may live through the winter in either the egg, larval or adult stage, though the former is the most common method for those belonging to our fauna. All our species of *Anopheles* hibernate as adults, but I know positively of only three species of *Culex* that they do so; these are *pipiens, restuans* and *salinarius;* all closely allied. Of *Culex melanurus, Corethrella brakeleyi* and *Wyeomyia smithii* it is positively known that they winter as larvæ. Of the others we know, either that they winter in the egg stage or we know nothing at all definite about them. It is generally fair to assume that when no trace of the species can be found in any other stage, that the egg lives through that dormant period.

This egg may be either in the mud of pools to be filled by the snow and winter rains, or on the bottom of pools already filled, ready, like that of *canadensis,* to hatch at the least provocation.

The adults, when they hibernate, seek any shelter that will protect them from the direct influence of the weather. Mr. Brakeley has made an interesting hunt for *Anopheles* and has found them under overhanging banks, among the roots of trees and in "varmint" holes in sloping banks; wherever, in fact, there was opportunity for shelter. They, as well as the *Culex,* have also been found in hollow trees and logs and, out-doors, there seems to be no one place more especially favored than another. In settled communities all these species favor the cellars of barns and other buildings. In a vacant house specimens may be found in any room; but the cellar usually contains more than all the others taken together. In barns and other outbuildings they

hide among the rubbish and in boxes or barrels, preferring usually the lower portions and the side of the foundation if that is of stone. In houses that are inhabited, the specimens are largely confined to the cellars and, preferably, to the lower part of the side walls, though they may be found anywhere. When the cellar is warm, either because there is heat in it or because the outside temperature is high, the insects are readily disturbed and, while by no means as active as in summer, they fly when the attempt is made to pick them off. When the weather is cold the body is brought closer to the surface, the legs are more bent and drawn near the body, taking a position which Mr. Brakeley calls the "hibernation squat." In this position they are really dormant and allow themselves to be picked off with the fingers. When the weather is very cold they will fall to the ground when pushed from their hold and will lie there until revived by a rise in temperature. *Anopheles* seems to become less completely dormant than *Culex* and it is curious to find this species abundant sometimes, in hibernating quarters, where little or nothing is seen of it in summer. Thus at Lahaway, while Mr. Brakeley could find larvæ in small numbers at almost all times after early summer, adults were rarely met with and were never abundant. Yet in winter the cellar of the dwelling house and the cranberry house, yielded several thousand hibernating *A. punctipennis*.

In the cellars of factories close to the marshes, thousands of *Culex salinarius* were found on the walls and ceilings, though that was the least troublesome of the species in summer.

As the matter stands from our present knowledge, the species hibernating as adults are all troublesome, and any method that will relieve us of them, even in large part, will be a direct benefit because it will delay their multiplication in spring.

DESTRUCTION OF HIBERNATING ADULTS.

The importance of a systematic and thorough dealing with the winter stock of both the *Anopheles* and the common house mosquito was fully appreciated and for the purpose of making some practical experiments I obtained the assistance of Mr. George J. Keller, of Newark, a graduate in pharmacy with some knowledge of insects and an especial knowledge of vegetable poisons, among which I hoped to find some material that would serve to destroy the insects without endangering human life or health or injuring either fabrics or metals.

There are probably few cellars in Newark, Elizabeth and other cities where mosquitoes abound, in which there is not, during the

winter, a population of hibernating mosquitoes. These hibernates, and especially the house mosquito, *Culex pipiens,* breed in so great a variety of places that it is of the utmost importance to check them at every point. Permanent eradication of all breeding places is impossible as against a species that will breed in every sewer catch-basin, in every settling basin in the park drains and in every cess-pool, manure pit or cistern which is in any way open to the air. These things are necessities in modern cities and the sewer catch-basins as at present constructed are open invitations for breeders. This, chiefly, makes the destruction of the hibernates of importance, for all of them are impregnated females and all of them are potential progenitors of between 400 and 500 specimens. Of course not ten per cent. of those that get into the cellars in fall live through the winter; but every additional per cent. destroyed by artificial means is a positive lessening of the supply that will be felt throughout the ensuing summer. As the ordinary winter population of a city cellar is rarely less than 100 and often reaches 1,000 the chance for effective work is obvious. Mr. Keller's report which follows will give interesting information concerning the favoring factors. So far as the discussion of remedies goes, this chapter in part anticipates another section of the Report; but as the subject really stands by itself it is deemed best to present it here as a whole.

We have, of course, absolutely effective agents for destroying the hibernating specimens; but all of them are open to some serious objection. The hydrocyanic acid gas formula is as follows:

For every 100 cubic feet of space use—

Cyanide of Potassium, 98 per cent. pure, ...	1 ounce.
Sulphuric acid, best commercial, ...	2 ounces.
Water, ...	4 ounces.

Add the acid slowly to the water in an earthen dish or jar and then drop in the cyanide in a paper bag. The paper retards the formation of gas slightly and enables the operator to get out. This gas, formed by the action of the diluted acid upon the cyanide, is deadly to all animal life and that fact forms the greatest objection to its use. In dwelling houses it is cut out altogether and where it is to be used in public buildings, factories or churches, the cellars should first be made as tight as possible and after the fumigation is started the building should be left closed for at least twenty-four hours before it is entered. Arrangements should also be made for opening up the fumigated

Figure 14.

Salt marsh breeding area, caused by elevating a railroad dam without providing for drainage through it. (Original.)

rooms from the outside so as to give the gas a chance to escape or become diluted before they are entered. Incidentally this treatment will reach rats, mice and other vermin as well. For large spaces this is much the cheapest process and, used with a knowledge of the danger involved, is reasonably safe.

Sulphur burned over a water bath at the rate of one pound for every 500 cubic feet of space is another effective agent; but this attacks metal and bleaches fabrics, so its use is excluded in many places. Where, however, there is nothing to be harmed by it, the large sulphur candles made for disinfecting purposes may be satisfactorily employed by burning on a brick in a tub or other shallow vessel partly filled with water. This is also a reasonably cheap application.

Formaldehyde stupefies but does not kill and the same is true of pyrethrum, tobacco and some other narcotics, all of which also are too expensive when used in such quantities as might be expected to make the stupor permanent.

With this introductory explanation the importance of Mr. Keller's results will be apparent, because the *Datura stramonium* or "Jimpson weed," which he found effective, occurs almost everywhere and may be prepared by anybody at small expense, and because it is harmless to man in such quantities as might escape from a well closed cellar into a dwelling house above.

Mr. Keller's Report.

Pursuant to your request, I beg leave to submit a report on the investigation and experiments carried on by me to find a practical method of destroying the hibernating species of mosquitoes. Contrary to the statements made, that none of these troublesome creatures were to be found in hibernation in the particular territory where I carried on my investigations, my results prove that hibernating mosquitoes are found more or less numerous in at least 75 per cent. of all the cellars in the city of Newark. Of 24 cellars, situated in different sections of the city, I found mosquitoes present in 17. For convenience I shall number these infested cellars consecutively, numbers 1 to 17.

Cellars numbered 1, 2 and 3 were located on Seymour avenue; moisture quite noticeable, although floors were cemented, brick foundation, not whitewashed. Mosquitoes were found in numbers congregated near the water-supply pipe, especially in cellars 2 and 3. In cellar number 1, however, the insects were not found in colonies, but all over, having been disturbed several hours before I inspected the place.

Cellars numbered 4 and 5 are located on Springfield avenue. Cellar number 4 was fairly moist, walls whitewashed, but not of recent date, brick foundation. In this cellar a considerable number of mosquitoes were found, but all in somewhat of a dazed condition. They would not fly or crawl from their hiding places even if urged on to do so, and hundreds were found clinging to the wall in the dark portions of the cellar. Cellar number 5 was quite dry, not whitewashed, and here large stones were used in building the foundation. Ventilation not very good. Mosquitoes were found in very small numbers.

Cellars numbered 6, 7 and 8 are located on Hunterdon street. Cellar number 6 was quite dry, cemented floor, brick foundation, partly but not recently

whitewashed, ventilation good. Here mosquitoes were found clinging to those portions of the wall where the whitewash had peeled off. Cellars number 7 and 8 were very dry, cemented floor, large stone foundation, thoroughly whitewashed; very few, not more than two dozen, insects were found in the dark portions of both cellars.

Cellar number 9, located on South Fourteenth street, was quite dry, cemented floor, brick foundation, no whitewash, good ventilation. In a very dark corner of that cellar, in the neighborhood of the water-meter, hundreds of mosquitoes were found.

Cellar number 10 is located on Somerset street. It was expected that mosquitoes would be found there in large numbers, because the cellar was very dark and afforded an ideal hiding place for the insects. The walls of the foundations were built of large stones, not whitewashed, plain sand floor, ventilation poor. Only about half a dozen insects were found. Upon closer examination I could not find any place where the insects could find easy access to the cellar, although my report on cellar number 15 will show a veritable storehouse of hibernators, with no discernible access for the insect.

Cellars numbered 11 and 12 are located on South Sixth street. Atmosphere damp, brick foundation, no whitewash, plain sand floor, ventilation fairly good. Mosquitoes were noticed in numbers on walls facing the yard, where moisture slowly percolated through the porous bricks. On account of the constant use of the front part of the cellar, where coal was stored, no mosquitoes were found there.

Cellars numbered 13 and 14 are located on upper Bank street. Cellar number 13 was dry, cemented floor, brick foundation, whitewashed, ventilation good. Mosquitoes were found in a dark compartment of the cellar, but not in numbers. Cellar number 14, however, was somewhat moist, and the insects were found near the water-supply pipe.

Cellar number 15 is located on Hamburg Place road. If every cellar in the city of Newark harbored as many hibernating insects as this cellar did, there would be no comfort for the citizens of that city; they would have to take to the hills to escape the horrible pest. To count the insects would be a herculean task. Thousands upon thousands decorated the naked brick walls, and the pillars of masonry in the center were practically alive with them; an occurrence which I did not notice in other cellars, the mosquitoes usually clinging only to those walls facing the street or a yard, but rarely to dividing walls in a cellar. This unusual occurrence I might explain by the suggestion that the insects were so numerous in a space of one hundred and twenty-five feet by fifty that those arriving first selected and monopolized the outer walls, whereby the late comers were compelled to make use of the inner walls and pillars. This cellar is by no means a very damp one, yet there is considerable moisture to be found at times, and large areas of swampy ground are in close proximity to the building. It was puzzling to me, as well as to your Mr. Brehme, how the insects could have gained access to the rooms, for there were no windows broken nor apertures left for an entrance. I would suggest that this particular cellar be fumigated in the latter part of the summer to drive out whatever insects are to be found therein, and the walls be thoroughly whitewashed.

Cellars numbered 16 and 17 are located on Monmouth street. Cellar number 16 is very moist, ventilation good, brick foundation, not whitewashed, partly cemented floor. The insects were found here in numbers on the wall facing an alley; but on the opposite side, on the wall dividing the cellars of a double house, none were found In the other cellar of the double house the insects were found just as numerous, also facing an alley. My supply of experimental material was taken from these cellars, and the supply appeared to be inexhaustible. Cellar number 17 is very dry, brick foundation, whitewashed, cemented floor. Very few mosquitoes were found in this cellar, albeit located close to cellar number 16. I also examined a cellar in Elizabeth, as per your instructions, and found, in a well-ventilated, partly whitewashed cellar, a small number of mosquitoes. I was about to give up the task, as I considered the place not a very favorable one for my investigation, when I found, in a very dark portion of the cellar, a door leading to a dungeon-like

compartment. Here I found a colony of insects in a moist corner, near the water-supply pipe.

Before I relate the conditions prevailing in those cellars which were not found infested by the insects I would like to say something about the habits of the hibernating mosquitoes as they came under my notice. From the first day of the hibernation up to the months of January and February the insects are found on the walls of cellars, resting about from 6 to 18 inches from the floor of the cellar. As the season advances the insects find their low quarters uncomfortable. Their partly dormant vitality receives an impetus; they crawl or fly to higher quarters (I have noticed them as high as five feet only three weeks ago), where they remain until the warm rays of the sun urge them on to leave their winter quarters, to come out to the open, to be fruitful and to multiply.

I will proceed now to give a description of the cellars where no insects were found:

Cellar number 18 is located on Hunterdon street. Dry atmosphere, large stone foundation, thoroughly whitewashed, plain sand floor. This cellar was extremely dark, not a ray of sunlight ever entering its interior. No possible chance for a mosquito to enter.

Cellar number 19 is located on Lentz avenue. Moist atmosphere, brick foundation, walls whitewashed. I have no doubt that I would have found mosquitoes in this cellar, but the owner of the house conducts a butter and egg business, and it was his custom to leave the cellar door open during the winter, rendering the place a very cold one.

Cellar number 20 is situated on Gillet place. Dry cellar, floor cemented, brick walls, whitewashed, fairly good ventilation.

Cellar number 21 is located in Lyons Farms. Despite the assertion of the owner that mosquitoes would be found there in numbers, a thorough search produced a negative result. The cellar, from a sanitary standpoint of view, was immaculate. Floors cemented, large stones were used in the building of the foundation, thoroughly whitewashed, not a particle of moisture noticeable.

Cellar number 22 is located on West Kinney street. Very dry, fairly good ventilation, brick foundation, whitewashed, floor cemented. Cellar used for the storage of malt liquors.

Cellar number 23 is located on West street. Very damp, poor ventilation, brick foundation, partly whitewashed. This cellar appeared to be a good hibernating quarter for the insects, but close examination proved the negative. This cellar is also used for the storage of malt liquors.

Cellar number 24 is located on Monmouth street. This cellar was the vilest and most unsanitary I ever saw. Brick foundation, not whitewashed, plain sand floor, water in certain places three and four inches deep, and a leaky furnace expelling carbon monoxide added to this unsanitary condition. Malt liquors and carbonated beverages were stored here. In a general summing up of these last-named cellars, numbered respectively 22, 23 and 24, I account for the absence of the insects by the large quantity of carbonic acid gas present. A precipitating vessel filled with baryta water, placed at the height of 10 inches from the floor, reacted in 2 minutes, showing an unusual amount of carbonic acid gas present in these cellars. This gas being more than half as heavy again as air, its weight being 1,529, it will be found in more or less of a layer, according to the depth of the cellar or the ventilation, wherever fermenting liquids are kept. The gas is irrespirable in a concentrated form, but found mixed with air to the extent 5 to 7 per cent., as is the case in the aforenamed cellars, it acts as a narcotic poison, not alone to the human organism, but the animal organism as well.

Having thus given a description of where and how I found the hibernating insects, I proceed to the second part of my investigation, to wit: Experiments to find a practical method to destroy the hibernating mosquitoes. A good many materials have been tried to destroy the insects by means of fumigation, but either the material was found not to produce the desired effect or it bleached fabrics, corroded metal, etc., not to speak of some the use of which might result fatally to the operator. After a few weeks of experimenting I

demonstrated that the mosquito is particularly susceptive to the fumes of narcotic herbs. In the primary stage of my experiments I employed a mixture of 6 different vegetable powders, 2 of which were of a narcotic nature, the remaining 4 being employed as smoke carriers and aromatics. I came to the conclusion, however, that a mixture of that kind for practical use would be too complicated or difficult to obtain; therefore I set to work to root out those ingredients which were useless or those which could readily be dispensed with. For all of my experiments I employed a glass case (21 x 20 x 10 inches) in the dual capacity of execution box and test chamber to compare the combustibility of the different powders.

First Experiment: Test of Combustibility—Each of the vegetable powders was taken and mixed with one-third its weight of saltpetre to facilitate the process of combustion. They were separately ignited, and in this test powdered Foenugreek seeds was thrown out as useless, leaving five ingredients for the *Second Experiment.*

Weight and Density of Smoke—The same quantity of the five remaining ingredients was taken and mixed with Saltpetre, as in experiment number 1. The weight of smoke of the separate five ingredients was about equivalent. The smoke rose to the top of the chamber rather rapidly, being propelled by the explosion-like ignition of the combustion agent; from there, meeting with an obstruction in the shape of the top of the chamber, the smoke distributed itself uniformly, the only exception being Chenopodium, which had a dense, heavy smoke, due to moisture present. Under normal conditions, that is, when the powder is thoroughly dry, the weight of smoke was equivalent to the others, but a little more dense, which I ascribe to the presence of fatty oils. This experiment only proved the adaptability of the powders as fumigators, but not the effectiveness as an insecticide.

Test as to the Effectiveness of the Powders as Fumiferous Insecticides—This was by far the most interesting experiment of the three, the outcome of which caused me to modify the composition of my fumigating powder. Twelve live hibernating mosquitoes were captured, placed in the experimental chamber and subjected to the fumes of powder number 1 (Pyrethrum). I waited two hours for the fumes to take effect, and upon opening the cabinet the insects were found none the worse for their experience. They appeared to be somewhat weak, but readily revived upon admission of fresh air to the chamber. I killed these insects in a cyanide jar, as they were unfit for future experiments. A fresh supply of the insects was confined in the chamber and subjected to the fumes of powder number 2 (Chenopodium). It was noticed that the insects relinquished their hold on the sides and top of the chamber in 10 minutes, falling on their backs stupefied. In this condition they remained for almost one and one-half hours, but quickly revived when fresh air was admitted to the chamber. I decided to omit powder number 3 (Nutmeg) in these experiments, not alone because of its high commercial value, but because it served only as an aromatic in the composition. Powder number 4 (Hyoscyamus leaves) next was ignited and about a dozen insects were subjected to its narcotic fumes. The insects were found stupefied in about eight minutes. The chamber was kept closed for a period of two hours and all the insects died during that time.

Powder number 5 (*Stramonium* leaves) was next in turn. This drug proved to have the same effect as powder number 4, but appeared to be more powerful. The insects that were exposed to its fumes dropped to the bottom of the chamber in from four to five minutes and died in one hour in the closed chamber. These series of experiments proved to me conclusively that the dried and pulverized leaves of *Datura stramonium* are, so far, the best adapted to destroy the hibernating mosquito. The fumes are practically harmless to the human organism and, even if there was the slightest effect upon the system, a fatality ought not to occur, as there is no necessity for the operator to remain in the room where the powder is burning. Cellars number 11 and 13 were both subjected to the fumes of stramonium in my investigation, and from 80 to 90 per cent. of the insects were killed. Cellar number 6 was treated twice, the first time with the

original mixture of six ingredients, but the amount of narcotic herbs contained therein was very small; the insects quickly revived after the smoke had disappeared and I was compelled to prepare a stronger mixture, to the fumes of which at least 90 per cent. of the insects fell victims. In cellars number 9 and number 15 a strong mixture was employed with gratifying results, especially in number 15—this veritable bee-hive of hibernators. The result was beyond expectations.

In a cellar at Elizabeth I employed in one compartment chenopodium seeds, in the second compartment a mixture of chenopodium and stramonium and the third compartment stramonium only. The result was the following: In the first compartment the mosquitoes were found alive; in the second and third compartments they were found stupified. I visited the same place again four days after and found a number of dead insects in compartments 2 and 3. Unfortunately, I found the doors connecting these several parts of the cellar open, and whatever live mosquitoes had remained in the place were to be found in compartment 3, the darkest and most moist in the whole place. Wherever I used stramonium fumigating powder it was mixed with saltpetre in the proportions of three parts of drug to one of saltpetre. In order to produce the desired effect the cellars should be closed as tightly as possible, so as not to give the fumes a chance to escape. Spread the powder on a large piece of tin in a layer of, perhaps, not more than on-half an inch and, if the cellar area is a considerable one, use several of these tins. Ignite the powder on several ends in order to hasten process of combustion. It is absolutely necessary to keep the cellar tightly closed during a period of, at least, two hours. The smoke by this time will have partly disappeared, leaving no disagreeable odor. The quantity of the above-named mixture used in a space of 1,000 cubic feet is about eight ounces, which can be readily purchased at a wholesale druggist for about forty to forty-five cents a pound. In the latter part of my investigation I tried one experiment which I like to mention in this report. I have shown before that in cellars number 22, 23 and 24 the absence of mosquitoes was due to the presence of carbonic acid gas. The cheapest and most economical way of preparing this gas is by the burning of charcoal in an open furnace. The gas which is produced first, carbon monoxide, is somewhat lighter than air and will be found to rise to the upper portion of the cellar, but it soon will associate itself with sufficient oxygen to form a heavier gas—carbon dioxide, or carbonic acid gas. I have killed several mosquitoes in a very short time by placing a tiny furnace in my experimental chamber. Air (oxygen) was admitted to the furnace by means of a rubber tube, to which a rubber bulb was attached, keeping the charcoal in a continual blaze. This is a very cheap method, costing not more than fifteen to twenty cents for a cellar of even large area. The cellar should be closed tightly, the furnace or furnaces placed in a secure position, so as not to come in contact with any inflammable material. We know that this gas formed in the aforesaid manner is a dangerous one to the human organism, but not nearly as dangerous as the fumes of hydrocyanic acid, which have been recommended to kill insects and vermin of all sorts. Every person is accustomed to the use of charcoal and, knowing what effects the fumes have on the physical makeup, can readily guard against any fatality.

Before closing, there is one other point regarding the extermination of hibernating mosquitoes that might be of interest. My report shows that the insects were found not so numerous in cellars that were thoroughly whitewashed. Up to this date I cannot account for this occurrence. Various theories have been advanced by some of my acquaintances who have taken an interest in my investigation. Some of them said, and I at first thought it worth while noting, that the whitewash might have a poisonous effect upon the insects: others again maintained that the whitewash rendered a cellar light, and as the insects preferred to hibernate in dark places a ready explanation would be found in their theory. I tried a simple experiment. A one-quart jar was taken and the inner walls thoroughly white-

washed with pure hydrate of calcium. A second jar was treated in the same manner, carbonate of calcium being used in place of the hydrate. The principal part of a freshly-prepared whitewash is a hydrate of calcium, and after it is once spread on walls it undergoes a chemical change, due to moisture and other causes forming carbonate of calcium. Having taken this chemical change into consideration, the inner coating of jar number 1 represented the coating of a freshly-whitewashed cellar, and that of jar number 2 the coating of a whitewashed cellar not of recent date. Several mosquitoes were confined in each jar and kept there for over ten days, with the result that only one insect died out of six in jar number 2. The insects confined in jar number 1 were somewhat inactive, due to the strong odor of the hydrate, whereas those confined in jar number 2 were lively and eager to be taken from their prison. The second theory, the cellar being rendered light by a coat of whitewash, is not a plausible one, the whitewash acting only as a reflecting agent from the light without and, besides that, I have noticed hibernating insects in light places, although, as a rule, they are found in dark corners.

Respectfully submitted,

GEORGE J. KELLER.

Newark, N. J., April 25th, 1904.

CHAPTER VI.

MOSQUITOES AND DISEASE.

That certain febrile diseases and some others depend upon mosquitoes for their continuance and for their transmission from one individual to another is now generally accepted as proven. So generally, indeed, that preliminary to beginning work on the Panama Canal the engineers in charge have arranged to improve sanitary conditions and lessen the danger from tropical fevers by draining or otherwise dealing with mosquito breeding localities along the line. Most, if not all, the pernicious "swamp" and "jungle" fevers are now traced to them with more or less certainty, and the control of the mosquito pest is an accepted principle of sanitary practice.

Yellow fever, one of the most dreaded diseases of the Southern States in our own country, has been positively proven to depend upon *Stegomyia fasciata,* a mosquito which, fortunately, has not been found in New Jersey. The actual life cycle of the germ or organism causing the disease has not yet been followed out; if, indeed, it is certainly known; but the experimental evidence is complete. Other tropical diseases, like *filariasis* and *elephantiasis,* are known to be carried by these insects, and their agency in yet others is suspected.

No one genus of mosquitoes can be considered a universal disease carrier, and some species that are not known to carry diseases of man do carry diseases of birds and probably of other animals.

In New Jersey the only diseases influenced by mosquitoes are the various forms of malarial fever, and only the species of the genus *Anopheles* are known to be active in its transmission. To be entirely accurate, only one of our species, *A. maculipennis*, has been actually demonstrated as a carrier of the disease. Neither *punctipennis* nor *crucians* have been definitely proven to be hosts for the parasite; but, as in other countries, other species than *maculipennis* are known to be dangerous, the two species mentioned must be looked upon with distrust until actual experiment proves them harmless. I have elsewhere given the reason why this demonstration could not be made in the present investigation.

The entire life cycle of the malarial parasites has been worked out and the history of the investigation and of the actual experiments made are detailed by Dr. H. P. Johnson in an appendix to my Report to the Experiment Station for 1902. For present purposes the experiment record may be omitted and Dr. Johnson's account of the parasite, its development and its relation to both man and mosquito is given, with such additions and explanations as the change in form makes necessary. So far as possible matter directly quoted is given in quotation marks.

"There is a widespread misapprehension regarding the way in which malaria is transmitted by mosquitoes. Many who unhesitatingly accept this view are unable to explain upon what foundation it rests, or why it has so quickly won the acceptance of biologists the world over. Many, even of the medical profession, attach little or no importance to the really great differences in the modes of existence of the various disease germs. Hence it is not surprising that they should regard the malarial organism as a germ of the same sort as bacteria, endowed with the well known power of most bacteria to live outside the animal body and withstand cold, heat, dryness and other adverse conditions. If this were so, modes of transmission other than that by mosquitoes would require the most careful consideration. No reputable pathologist or bacteriologist would venture to assert that one might not contract malaria as one contracts typhoid or diptheria or smallpox. The simpler the life history of a pathogenic organism, the greater the variety of conditions under which it can lead an active existence. As compared with bacteria, the life history of the malarial organism is exceedingly complex; accordingly we find its conditions of existence vigorously

restricted. So far as known, not one of the whole great group of the Sporozoa (literally, spore-producing animals), to which the malarial organism belongs, can lead an active existence outside its appropriate host. Without exception they are obligatory parasites," depending for their actual life upon the presence of the host. "Probably all of them pass at least a portion of their cycle within the very cells of their host. It is not surprising, therefore, that not one of the Sporozoa has been found to lead a saprophytic existence; that not one has been cultivated outside of its host.. With the bacteria, on the contrary, it is the exception that they cannot be reared on nutrient media."

"The host species of any Sporozoan are always few and closely restricted; frequently there is only one. Again, within the body of the host these fastidious parasites elect only cells of a certain tissue, and often even that tissue as it occurs in some particular organ. Thus, the entire order Hæmatozoa, to which the malarial organism belongs, live in the red blood corpuscles; but in no other part of the vertebrate body. Here they are completely shut in from the outer world to which they have no direct access. The blood-sucking habit of the mosquito affords them an exit: first, to the mosquito's body, where they pass through a cycle different from that in the blood; and then, by the agency of the mosquito, back to the circulation of man, beast or bird, according to the special form of malaria."

The Hæmatozoa differ from the rest of the Sporozoa, inasmuch as they live in two hosts, vertebrate and mosquito or some other blood-sucking parasite. In all forms of human malaria yet investigated the carrier host is a mosquito of the genus *Anopheles.* This reveals the highly specialized nature of their parasitism. *Culex,* so nearly related to *Anopheles,* so like it in all its structure, physiology and habits, cannot become infected, so far as we know, with any form of human malaria. On the other hand, the malaria of birds, which differs slightly from human malaria, cannot be transmitted by the agency of *Anopheles*, but only by *Culex*."

"Can any species of Sporozoon pass from host to host without an animal carrier? The answer to this question concerns us much. As soon as it is demonstrated that even one form of the disease-producing Sporozoon can pass from one vertebrate to another, we naturally inquire whether this may not be the case sometimes with the malarial parasite also. The answer is, emphatically, no! Notwithstanding there are numerous Sporozoa which pass from one host to enter another of the same species, with an intermediate sojourn in the outer world, this passage is made in the form of encysted spores. Encystment is absolutely necessary to

protect these delicate organisms from dessication. Since no encystment occurs with the malarial germ, or with any of the known Hæmatozoa, we are justified in concluding that direct transmission is impossible for them. Like the seed of a plant, the animal spore must reach a suitable soil before it can germinate, and the only suitable soil is the body of its appropriate host."

In parasitology the terms "intermediate" and "definitive" host have been applied. In the first case to designate the organism in which the asexual reproduction occurs and in which the parasite does not reach its full development. The "definitive" host is that in which the sporozoan becomes sexually mature, conjugates and produces the stage by means of which it may be introduced into the "intermediate" host. Applying these terms as in the past, malaria becomes a disease of the mosquito, one stage of which is passed in man as the "intermediate" host.

"Nature does not adopt roundabout methods when direct ones will serve her ends. To the parasitologist, therefore, the fact that experiments have shown beyond a doubt that malaria is transmitted by mosquitoes is sufficient proof that this is the only means of transmission."

"We may, accordingly, dismiss once and for all, the time honored but never proven doctrine that malaria germs lurk in damp soil or float in the miasma of swamps, ready to infect mankind whenever the soil is disturbed or the swamp air breathed. That we may get malaria from swamps and in consequence of breaking the soil cannot be denied; however, we get it, not directly, but because these conditions favor the breeding of *Anopheles*."

"At the outset it is necessary to define just what is meant by 'malaria,' for many and diverse ailments masquerade under this convenient guise." Physicians sometimes diagnose as "malaria" a general malaise characterized by a slight fever, which is relieved by administering quinine. "Again, there may be a 'chill' as well as a fever. Even this does not prove a case of malaria, which can be diagnosed with certainty only from the blood. Unless, after reasonably diligent search, the malarial germ (Plasmodium or Amœbula) is found in the blood, it is safe to conclude the disease is not true malaria, no matter what the symptoms. The malarial paroxysm or 'chill' is undoubtedly the most reliable clinical symptom, but it is not infallible."

"If freshly drawn malarious blood is kept at body temperature and protected from the atmosphere, the plasmodia in the corpuscles may be seen to exhibit active streaming or amœboid

movements; hence the names 'Plasmodium' and 'Amœbula' are very appropriate. The Plasmodium remains constantly within the corpuscle and feeds upon it. The hæmoglobin of the corpuscle is the source of the characteristic pigment seen in the plasmodium. Eventually the corpuscle is destroyed. The application of a suitable dye to a blood smear on a glass slide or cover glass, stains not only the plasmodium in its entirety but also its nucleus, thus demonstrating that the malarial organism is a cell. It is, in fact, a unicellular animal, a protozoan."

The common type of malaria in New Jersey is the tertian, in which the paroxysm occurs every other day. The quartan, in which the chill recurs at intervals of seventy-two hours, is comparatively rare. The æstivo-autumnal fever, in which the chills come at irregular intervals, is an introduction from Southern Europe and has undoubtedly obtained a foothold with us.

It is now recognized that these three types of malaria are caused by as many distinct species of parasites, each distinguished by well marked characters. Thus tertian fevers are produced by *Plasmodium vivax,* quartan by *Plasmodium malariæ.* and æstivo-autumnal by *Laverania malariæ.* Where, in a case of tertian or quartan malaria, a chill occurs every day or at irregular intervals, it is due to a double infection.

"In every form of malaria the chill marks an important epoch in the life history of the parasite. At this time 'sporulation' is taking place—that is to say, the plasmodia, having attained the limit of their individual growth, and having used up all the nourishment afforded by the corpuscle, reproduce asexually. The nucleus divides into several daughter nuclei, and each of these gathers to itself its due quota of the living substance, the protoplasm, of the mother cell. The enclosing membrane of the used-up corpuscle now ruptures and the spores (known technically as the 'schizospores' or 'merozoits') escape into the blood serum and thence invade other corpuscles. In doing this they disturb the temperature equilibrium of the body, and the chill results. The giving of quinine is most effective at the onset of the chill, because, no doubt, the free spores in the blood are more exposed to the poisoning action of quinine than are the plasmodia in the corpuscles. If the fever is left to take its course, more and more corpuscles are invaded and destroyed; the patient gets worse. Whether a condition of effective resistance is attainable—in other words, whether we may at length become immune—is not known, because of the well-nigh universal use of quinine in all civilized countries, thus breaking up the fever before the body has time to develop any resistant power it may possess."

This purely asexual mode of reproduction by spores may go on in the blood for a long time; but not indefinitely. Sooner or later some of the plasmodia assume an appearance different from the rest. The difference is but slight in the tertian and quartan fevers; but in the æstivo-autumnal it is striking. In this form of malaria the plasmodia assume a semi-lunar form and are known as 'crescents.' A general name now applied to all these bodies is "gamete" or "gametocyte." On drawing a little of the blood in which these bodies occur and watching them closely under the microscope, some of the gametes distinguishable by slightly larger size will suddenly be seen to give birth to several actively lashing thread-like bodies, known as the flagella or microgametes. "These swim actively through the blood serum, and finally unite with other gametes which have remained inert, producing no flagellated bodies. The union of these two bodies—the inert macrogamete and the tiny, active microgamete—constitutes the process of fecundation. It is essentially the union of the male element (spermatozoan) and the female element (egg or ovum), which everywhere inaugurates the development of a new being. Only in the case of the malarial organism we have to do with a unicellular parasite, and one perfectly adjusted to a very special mode of existence. It was soon ascertained that 'exflagellation' (and consequently fertilization) never occurs until the blood has been drawn;" but it may occur anywhere else outside the human body.

In other words, within the human blood only the vegetative reproduction by spores can take place. When the gametes are produced they persist in the circulation for an indefinite period without change; but when removed, as by the bite of an insect, development begins at once. So far as we know it matters not what the biting insect is—whether fly, bug, mosquito or flea—flagellation and conjugation will take pace. This, however, is the limit to which development can go in places other than the stomach of an *Anopheles* mosquito. If the patient be now bitten by such a mosquito and some of the gametes absorbed with the blood, fertilization (figure 15, 6) takes place and the sexual cycle begins. "As the first result we get a little, worm-like body, the oökinet or vermicule, which works its way into the wall of the mosquito's stomach. The stage, shown in fig. 15, 8, is passed in the wall of the stomach. The subsequent stages, characterized by very rapid growth, occur apparently on the outside(i. e., the peritoneal surface) of the stomach; but, actually, just under the extremely thin, muscular and elastic layer, which is very distensile and stretches to accommodate the growth of the parasite. These large bodies soon become visible on the stomach of

an infested mosquito (fig. 16, four and one-half days after infection), with a low power of the microscope. Still, the growth continues (fig. 15, 9-15), and now we find that there has been a division of the nucleus and the more the amphiont (as it is called) increases in size, the more numerous become the nuclei. Each nucleus gathers to itself a stellate mass of protoplasm.

"Then within this mass still further divisions of the nucleus take place, the now minute daughter nuclei crowding to the surface of the irregular mass of protoplasm (fig. 15, 15). Each tiny

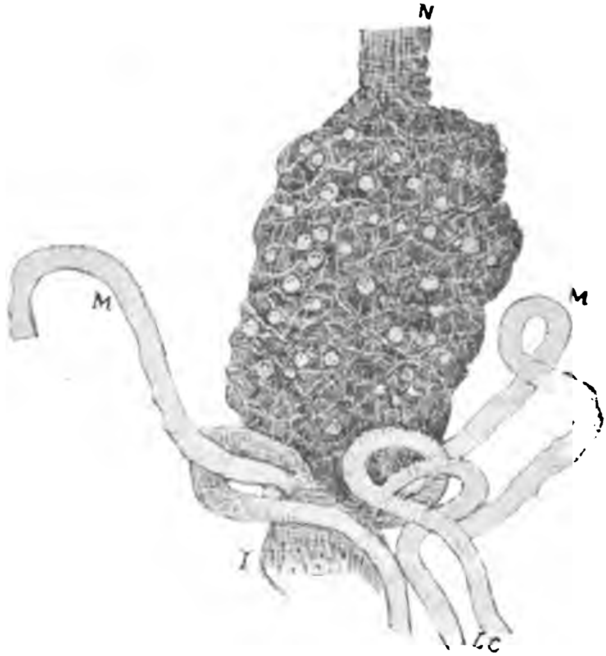

Figure 16.

Stomach of *Anopheles maculipennis*, showing the malarial zygotes 4½ days old in the meshes of the muscular fibres. N, neck of stomach; M, malpighian tubules; I, ileum.
(From Berkeley's Lab. Work with Mosquitoes.)

nucleus is soon the center of a rod-shaped body, and there are several thousands of these rod-like bodies (the sporozoits) in the enormously enlarged amphiont. Large groups of them lie parallel to each other, producing the characteristic striated appearance (fig. 15, 17). The capsule bursts and the 10,000 or more sporozoits are set free in the mosquito body cavity. Owing to some attraction of unknown nature, but presumably chemotaxis, they gather in the large vacuolated cells of the salivary glands. Thence

they are injected, with the secretion, into the first person the *Anopheles* bites, and after a short period of incubation that individual comes down with malaria."

When the sporozoits, or blasts, as they are also termed, are introduced into the circulation, each enters a red blood corpuscle and develops into a plasmodium, exactly as if it had been one of vegetative spores. The fact that there is an apparent period of incubation is explainable by the small number of organisms introduced which are not sufficient to produce a characteristic "chill."

How long the sporozoits retain their vitality within the mosquito is not known; but there is no reason why the same mosquito should not infect several persons, since experiment has proved that an individual will bite several times. Dr. Johnson records a specimen in captivity which bit him four times at intervals of two or three days. A specimen of Anopheles disturbed after biting and before feeding has already inoculated a victim and has an appetite whetted for blood which she may satisfy from another individual.

As the *Plasmodium* requires for its development within the mosquito body a period of from seven to ten days, the mosquito to be able to transmit the disease must bite after the sporzoits are developed. If it should bite even the day before and not again afterward the disease would not be transmitted. Any specimen that makes what would be normally its last meal on malarial blood will fail as a carrier.

Not all persons, though they may be suffering from genuine malaria, are in a condition to infect mosquitoes. There must be gametes in the blood in sufficient number to get into the peripheral circulation, so that a biting mosquito may get some of them. The malarial parasite lives through the winter in the human blood; it can live no other way, because the hibernating females do not feed before they go into winter quarters. That point has been satisfactorily demonstrated by Dr. Johnson, and my own observations bear him out to the full. It is quite likely, however, that individuals may bite during the winter in a warm house, for they become active very readily under the influence of even a moderate temperature.

On the other hand, there is every reason to believe that the organism may lie dormant in an individual for a considerable period, becoming active again when the physical condition of the host is favorable. Such individuals, too, may have the gametes present in the blood, even though not actually sick, and they may serve to start the disease in localities previously exempt. Several instances of that kind have come to my notice, where

severe cases of the æstivo-autumnal type were traceable to Italians engaged in railroad work, several of whom had had the disease, but were then apparently well.

The case against *Anopheles* is complete, so far as its relation to malaria is concerned, yet the work of the physician must be to cure the individual if he can, for if every case of malaria were absolutely cured before winter set in not all the *Anopheles* in the locality could start it again next year!

CHAPTER VII.

MOSQUITO STUDY AND ARRANGEMENT.

HOW TO COLLECT AND PRESERVE MOSQUITOES.

A collection of local mosquitoes in larval, pupal and adult stages should be part of the outfit of every health inspector in the State, and such a collection is easily made. To obtain all stages of the common house mosquitoes, *Culex pipiens* and *C. restuans,* it is only necessary to place out-doors a wooden pail or tub half filled with water, with a little vegetable mold or dead grass to start organic life. In a day or two egg-boats will be found on the surface of the water and, perhaps, eggs of *Anopheles* as well. These species lay their eggs at night and the boat ripens during the day following, young appearing in about thirty hours from the time of oviposition. If it is desired to preserve the egg boats, they can be placed in a little tube or bottle in 95 per cent. alcohol. If this is tightly corked the specimens will keep for a long time without attention. If the egg-boats are left in the pails to hatch, the developing larvæ may be watched from day to day until the first pupa appears. Then, whatever larvæ are needed for preservation may be taken and put into 75 per cent. alcohol. In a few days the 75 per cent. alcohol should be poured off and 95 per cent. alcohol added for permanent preservation. Tightly corked and alcohol added from time to time, as needed, these specimens will keep for years. As fast as pupæ appear they should be taken up with a wide-mouthed medicine dropper and placed either in alcohol to be preserved like the larvæ or in a quart jar, covered with a gauze hood. In from twenty-four to forty-eight hours adults will begin to issue and

will fly or crawl up into the gauze hood, from which they can be transferred into a bottle with a drop of chloroform or ether or into a regular cyanide jar. A better way is to have a large jar with a little chloroform on a wad of cotton, into which the hood with all its contents can be dumped and left until the insects are dead. They may then be shaken out of the hood on a piece of white blotting paper and are ready to be pinned. Pinning must be done with very slender steel pins, such as are used by entomologists; size 00, or, for the larger species, 0. The specimens should first be separated with fine tweezers—never handle a mosquito if it can be avoided—into males and females, and an equal number of each sex should be pinned. The pinning should be done for half the specimens through the middle of the thorax from the upper side, so that the insect will appear suspended in a resting position, and the pin should be driven for more than half its length through the body. The remainder should be pinned from the side, through the middle of the thorax, and thus there will be specimens that show uninjured every part of the body. Such specimens as are not to be pinned may be preserved in alcohol for future study; but after a specimen has once been in alcohol it will rarely make a satisfactory specimen for pinning, and some species practically lose all their distinctive markings, so that they cannot be surely identified afterward. Pinned specimens may be placed in any kind of tight box; but this should be cork lined.

All the apparatus, pins, bottles, etc., referred to here, may be obtained from the American Entomological Company, 1040 DeKalb avenue, Brooklyn, New York, and most of it also from the Bausch & Lomb Optical Company, and Kny-Scheerer Company, New York, and Queen & Company, of Philadelphia.

A very interesting plan when there are several egg boats, is to place each in a separate quart jar with some of the water from the pail, and preserve one set each day, so that a series showing the daily rate of growth may be easily obtained. Some of the cast skins of the later stages may also be preserved, and these lend themselves excellently well to mounting in Canada balsam for microscopic study. These cast skins may be taken up with a dropper and placed in 95 per cent. alcohol for an hour, a day or a year; at any time after the hour they may be transferred to a drop of liquid carbolic acid (Calvert's No. 4 or equivalent) on a slide, and left until they appear transparent. This will usually be a matter of minutes only, and then, when the acid is drained off, the specimens may be mounted in Canada balsam in the usual way without further preparation. This sort of mount will show the mouth structures, the anal siphon with its pecten of

spines, and the patch of scales. It will present only a confused mass as to the rest of the body. Pupa shells from which adults have emerged may be mounted in the same way.

Anopheles larvæ, when they are found in the trap pails or tubs, should not be removed except for preservation until they are nearly full grown. Experience has shown that they do not develop well in the laboratory in small jars. When about ready to pupate they may be brought in and dealt with as in the *Culex*.

Except for the *Anopheles* and the two species of *Culex* already mentioned, I have never found larvæ in my trap pails, no matter how plentiful other species might be.

Adult mosquitoes should be caught with a fine gauze net tapering to a long point. Just at dusk, when they begin to be troublesome on porches, they are easily seen and as easily caught with the net. From the net the individual can be transferred at once to the killing bottle or jar, or a number of specimens may be caught in succession by constantly keeping the caught specimens in the apex of the net by means of occasional jerky swings and allowing the long point to drop over the rim of the net. During the day, or when collecting in the woods, the net is easily managed, and with a very little practice a mosquito may be caught and transferred to a bottle absolutely uninjured. These collections made in the various localities are of great practical value, because they determine positively just what species are to be dealt with, and our present knowledge enables us to determine with reasonable certainty just where their breeding places are to be sought.

Where specimens are to be collected in a sick room for determination, or in a house under any circumstances, a tumbler with a wad of cotton having a good dose of chloroform is needed. The cotton must be fastened to the bottom so as not to fall out when the glass is inverted, and such a trap may be readily used with a little practice to capture mosquitoes sitting on side walls or low ceilings. Where specimens are out of convenient reach, a tin can fastened to a light stick may be used; but it will require a little practice to handle and place it over the insect without scaring it off. The chloroform acts very promptly and will stupify almost immediately, so that the specimen may be transferred unharmed to a vial or pinned, as desired.

Where larvæ are to be collected, with either the idea of determining the species or of breeding as many forms as possible from any one locality, the collector needs a supply of wide-mouthed bottles to hold his larvæ, a small beaker or thin glass holding about four ounces, a small net frame, six by eight inches in

Figure 17.

A mosquito collector's outfit. (Original.)

diameter, with a shallow cheese-cloth bag, and a medicine dropper of extra large size.

Every pool and every body of water, no matter how large or how small, whether clean or foul, whether in the dense woods or in the open meadow, should be tested with the glass. Even the springs from which he drinks should be dipped at the edges. The glass is used to make a preliminary test; a quick dip, or the draining of a grassy edge, will usually give at least a "show," if anything is present. If it does not at the first trial, several dips should be made until it seems reasonably certain that no larvæ are present. After a dip the glass should be held up to the light and any larvæ present will be detected in a few minutes, whether floating like *Anopheles* or submerged like *Culex*. If larvæ are present the net comes into service. This should be swept just beneath the surface, especially close to the edges, and as the water drains out the larvæ and pupæ are left squirming and wriggling in the sag, which may run to a little point. Turn this sag into one of the bottles and pour a little water through to wash the larvæ into it. But not only the surface must be collected over; some larvæ live habitually close to the bottom, just over or even in the layer of leaves and vegetable matter there to be found. To obtain these, patience is necessary, and the net must be used so as to take in some of the bottom material. Then holding the net so that it remains half filled with water, gradually remove all the debris and wash away the finest mud, leaving at last a liquid sufficiently clean to find the specimens, if any.

Some collectors use only a dipping glass, and from this the larvæ may be readily tubed out by means of the medicine dropper. Always put some of the water in which the larvæ were collected into the collecting bottles, and never attempt to transfer to clean water wrigglers taken in pools rich in organic matter. It is well to try to separate the larvæ according to their kind, as nearly as may be, in comparatively small breeding jars, that the resulting adults may be more certainly identified with the proper wriggler. Where it is of great importance, pupæ may be removed to small bottles as fast as formed, the cast larval skin being put into alcohol and the vial attached to the bottle containing the pupa. In this way the resulting adult may be positively connected with the early stages.

Four ounce, wide-mouth bottles are very convenient for breeding small numbers of specimens, and one or two ounce bottles answer for individual pupæ. All transfers should be made with a medicine dropper and the less the specimens are interfered with the better they will develop.

After all, the collector will learn rapidly by experience just what outfit he needs and how he can obtain the best results. What has been said above is in the main suggestive.

It might be added that a pair of rubber boots is often a great convenience on a wriggler hunt and a necessity on an undrained marsh.

HOW TO STUDY MOSQUITOES.*

The dissection and preparation for microscopical study of the various parts of the mosquito may be readily accomplished, after a little practice, with good results. Only a few instruments are really necessary, but all the following will be found useful. A dissecting microscope, or if this is not at hand, a good hand lens mounted above a stage, a pair of dissecting needles, a spear pointed needle, a few watch glasses, two or three droppers and a supply of slides and cover slips. A few substances will also be required as media for examining, staining or mounting the specimens and it will be necessary to have on hand ninety-five per cent. alcohol, absolute alcohol, carbolic acid, chloroform, balsam dissolved in chloroform and xylol and some normal salt solution. Of the above instruments the spear point may be dispensed with, and a needle used in its place; but the spear point will be found much more convenient. A small alcohol lamp is always of advantage in microscopic work and asphaltum will also be found useful in ringing slides, especially in preparing dry mounts.

The first step in preparing a specimen is the killing. This may be done by using a cyanide tube, or a few drops of chloroform, or by simply dropping the insect in alcohol. Either of the first two means should be employed if the specimen is to be pinned or used for fresh dissecting; but if the specimen is to be used for future microscopical work, or examination, the last method may be employed. Good mounts of the external parts may be made from dry specimens; but for examining or studying the internal anatomy only fresh specimens can be used.

The external structures which have been examined and studied in our work are the head with its beak, antennæ and palpi, the legs, the wings and the genitalia. In examining or dissecting a specimen, laying it upon a slide is sometimes recommended; but this will be found to be not so convenient or satisfactory as placing it in a watch glass. If, however, it is desired to examine a single part or structure it is best to remove this and examine it

* Prepared by Mr. E. L. Dickerson.

in alcohol or carbolic acid upon a slide. This is most easily accomplished by adjusting the part to be examined upon a slide, laying the cover slip upon it and allowing the alcohol or acid to run under. The carbolic acid has the advantage of not evaporating as rapidly as the alcohol, which has to be renewed every few minutes, and of clearing the specimen to some extent, when left in it for a sufficient length of time.

The wings are best examined dry and are so mounted. This is accomplished by making a ring of asphaltum with a turn table, or in any other way upon a slide, then placing a single wing or pair of wings within it and, before the asphaltum is dry, placing the cover slip upon it. A small camel's hair brush will be found most useful in making the ring. The cover slip should not be placed upon the ring while it is too moist, otherwise the asphaltum will be drawn under it and will spoil the mount. Other objects to be preserved dry may be treated in the same way.

In mounting the legs the same method is employed which is used in making nearly all our insect mounts. The specimen is placed in alcohol long enough to harden and dehydrate it. It is then passed through carbolic acid for a longer or shorter time and mounted in pure balsam or balsam dissolved in xylol. This can be accomplished with the object on a single slide, by simply drawing off one liquid with a bit of blotting paper and replacing it with another liquid. If the balsam is a little thick, its running under the cover slip may be facilitated by heating the slide sightly, but care should be taken that it is not heated to such an extent as to shrivel the specimen.

It is sometimes necessary to clear a specimen more than can be done with acid and this can be accomplished by first placing it for a few hours, if necessary, in liquor potassa. If this is done the specimen should be thoroughly washed with water before running it through the alcohol and carbolic acid. This clearing will not be necessary in mounting the legs of *Culcidæ*, but may be found useful in the case of the head and genitalia. The latter do not stand the treatment of running through ordinary alcohol and acid into balsam, but good results have been obtained by mounting them in balsam dissolved in chloroform. If this is done the specimen, after being in alcohol, should be thoroughly dehydrated and hardened by passing it through absolute alcohol. It should then be passed through chloroform and finally mounted in chloroform balsam. If the specimen is sufficiently hardened, little or no contraction will take place except perhaps in the terminal joints of the antennæ which, however, do not appear to be in any way characteristic. If the specimen is thoroughly dehydrated, passing it through chloroform may be omitted.

Dissections and examinations of the internal anatomy can be satisfactorily made with fresh specimens only, as the internal structures of those which have been preserved in alcohol are in such a condition as to be of little or no value except for determining the development of the ovaries. The dissecting should be done in a weak salt solution. Six tenths of one per cent. is recommended by Berkeley,* and if the solution is to be kept, it should be filtered, sterilized, stoppered with cotton and the dropper used should also be sterilized, otherwise the solution will not keep clear. However, tablets are now prepared for making a normal salt solution, so that it will be easier to make up a fresh supply when wanted than to save it. In examining the dissections, care should be taken to place a hair or something similar under the edge of the cover slip so that the object will not be pressed out of shape.

The internal structures, which can be readily found with a little practice, are the alimentary canal with its appendages and ovaries. The other structures—the respiratory, circulatory and nervous organs—will not be readily seen upon ordinary examination, although portions of the nerve cord with ganglia, and bits of trachea, or air tubes, will sometimes be observed. The alimentary canal, beginning in the head at the base of the beak, extends the length of the body. In front is the gullet or œsophagus, which extends half way through the thorax to the anterior end of the stomach, at which point three suctorial vesicles are attached, two of them situated in the thorax, while the third or middle one, being longer than the other two, extends backward into the abdomen. Generally they are filled with small air bubbles and thus are more easily seen. The stomach consists of two parts, the narrower portion, situated in the thorax, and the larger, situated in the abdomen, from the posterior end of which the intestine extends to the extremity of the abdomen. At the beginning of the intestine five large, rather short processes are given off, known as the Malphigian tubules, which are supposed to be urinary in function. In the posterior end of the abdomen in the female a pair of ovaries will also be found, situated one on each side.

To obtain good specimens of the alimentary canal, first remove the legs and wings—which is aways best to be done in making fresh dissections—then cut off the head, remove the upper surface of the thorax and free the alimentary canal from the remaining portion and in like manner from the abdomen.

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* Laboratory Work with Mosquitoes, by Wm. N. Berkeley, Pediatrics Laboratory, 254 West 27th street, New York City.

Another method recommended is to remove everything except the thorax and abdomen and to separate the last two segments of the latter. Then by gradually pulling on these and holding the thorax by the base of the forelegs the alimentary canal will be drawn out. If the stomach alone is wanted, the same method may be pursued with the abdomen alone, or after removing the abodmen, the stomach may easily be worked out.

The salivary glands—also appendages of the alimentary canal —are situated in the fore part of the thorax, below and on either side of the alimentary canal just above the forelegs, and they consist of three lobes on each side. From each group of lobes there extends a duct which joints its fellow to form a common duct, which passes forward and enters the fore part of the gullet or œsophagus. To dissect out these glands, cut away everything except the head and the fore part of the thorax. Carefully pick off the upper surface of the latter and gently pull the head away, holding fast to the lower part of the thorax. When this is done the glands will generally be drawn away with the head and then by carefully cutting very close to the head the glands will be removed with other material. They can be separated with a little care and practice, although I find it rather difficult to secure both glands together.

Permanent mounts of the internal structures cannot be made satisfactorily by any method that we know of without contraction occurring. Grassi recommends conditionally, two per cent. commercial formaline in 75-100 per cent. salt water. In this case the cover slip must be ringed with a cement. Grassi also suggests a fluid consisting of white of egg, 1-5 grains of salt and 250 grains of water. The material is beaten and filtered. The object in the fluid is placed on a slide, fixed in osmic acid, and mounted in glycerine.*

For staining, picro-carmine, eosin or nigrosin will be found useful, and I have had some good results with the latter. If the first method of mounting is used, the stain may be run under the cover slip and afterwards glycerine added, or as Berkeley recommends, 1 per cent. carbolic acid in glycerine. The cover may then be ringed.

The preparation of paraffine sections or similar work does not come within the scope of this volume. For this work and other microscopical preparations, Lee's Vade Mecum† should be consulted.

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* Quoted from Berkeley previously cited.

† The Microtomist's Vade-Mecum, by Arthur Bolles Lee, J. & A. Churchill, Great Marlborough street, London.

PART II.

Checks and Remedies.

CHAPTER I.

NATURAL ENEMIES.

All the insects, as well as other animals, have their natural enemies, and mosquitoes are no exceptions to the rule. The adults are taken by spiders, by numerous predatory insects, by frogs, toads, lizards, bats and birds. Few of these are specifically mosquito destroyers, but are insect-eaters in general and devour mosquitoes as they do everything that comes in their

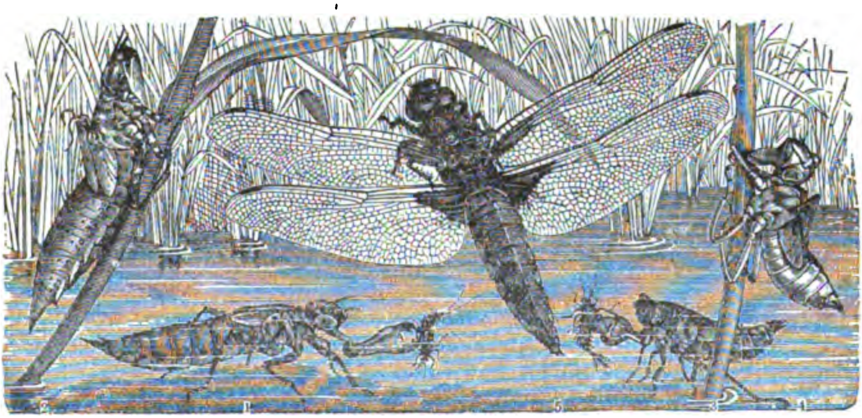

Figure 18.

The transformation of a dragon fly: 1, larva with its jaws extended; 2, pupa skin from which adult has issued; 3, active pupa feeding; 4, pupa on stalk ready to transform; 5, adult dragon fly.

way, the bulk of a meal being made up of whatever is present in greatest abundance and most easily obtained.

Those birds and other animals that are active only during the day, retiring to roost as the sun sinks below the horizon, are of comparatively little use. They may and do pick up odd specimens here and there and some, where mosquitoes are plenty,

may devour a great many; but they are not factors of great importance in the practical control.

Of course, this limitation applies to insects also, and none have a greater or more undeserved reputation as mosquito destroyers than the "dragon-flies," "devil's darning needles," "snake doctors" or "spindles," to whom the name "mosquito hawks" has been quite unjustifiably attached. "Dragon-flies" are as essentially creatures of the day as the mosquitoes are of the night. They frequent the open spaces around ponds and streams, the roads and fields in the full sunlight, and never by any chance the woodland or those dark moist recesses where their supposed prey spends the daylight hours. They are creatures of the air, ever on the wing when the sun shines and resting in the open on exposed twigs and branches. In the early evening, as soon as the shadows lengthen, a more retired spot is sought, and long before the mosquitoes find it pleasant to move, the "mosquito hawks" are fast asleep. Who ever saw a "dragon-fly" hunting among the grass for mosquitoes? and who has ever seen "dragon-flies" systematically hunting mosquitoes at any time? The "dragon-fly" captures its prey while on the wing, holds it with the legs, which all converge to one point for this especial purpose, and devours it while in flight. The mouth of the "dragon-fly" is so arranged that the food must be presented to and practically pushed into it. It would be an impossibility for the insect to crawl among the grass and pick up with its mouth parts a creature resting on the blade or hidden near the ground. I have watched "dragon-flies" of different species for many minutes at many times, but never saw one of them capture a mosquito—which is no direct proof, of course, that they may not do so. I have been on the salt marsh when mosquitoes were busy about me and where "dragon-flies" were rather plentiful, but though they came quite close to me, none made the least attempt to capture any of my attendants. I am sorry to discredit a popular belief, but I cannot find as the result of my observations that "dragon-flies" in the adult stage materially lessen the mosquito supply.

The effective species are those birds and beasts that begin to fly and prowl about in the twilight, when the mosquito itself is awing. Birds like the whip-poor-will, which add character to the hour and place, or like the "night-hawk," which flies swiftly and silently where mosquitoes at that time abound. Animals like the toad, which is as silent and adroit as it looks clumsy, and which picks up mosquitoes in quantity while waiting for something more substantial. Of predatory insects there are many

abroad in the evening and all night, indeed; but which and how many of them eat mosquitoes I do not know.

Spiders destroy an enormous number of adults. I have frequently looked over a series of webs in the morning and found only mosquitoes in the toils; sometimes one or two only, sometimes a great bunch of them reduced to little balls or dry husks. It is probable that many spiders subsist largely on mosquitoes and are among their most effective checks.

Adult mosquitoes are sometimes infested with little parasitic mites, bright red in color and usually attached to the underside of the body behind the wings. This looks like and may be the same species that is found on the common house-fly, but the two have not been critically compared. Usually this mite is so rare as to attract no attention; but sometimes, as in the early summer of 1904, it may become locally so abundant as to attract general attention. The effect of this kind of attack is to weaken the insect and perhaps to shorten its life, while preventing reproduction. Unfortunately, we know little of the life history of these minute parasites, or how they came to attach themselves to their hosts.

Agamomermis culicis.

A more effective enemy, unfortunately attacking only a single species, so far as known, is the round worm described by Dr. Charles Wardell Stiles as *Agamomermis culicis,* in Bulletin No. 13 of the Hygienic Laboratory of the Marine Hospital Service. The following is a copy of the description and of Dr. Stiles' comments:

"Group AGAMOMERMIS, Stiles, 1903.

"Generic diagnosis.—Mermithidæ: An artificial collective group containing larval forms, which cannot be more definitely determined because of lack of genital organs. As such a group is artificial, it should have no type species."

"Species AGAMOMERMIS CULICIS, Stiles, 1903.

"Specific diagnosis.—Agamomermis: About 11 mm. long; 240 u. in diameter. Caudal spine, 88 u. long.

"Habitat.—Abdominal cavity of Mosquitoes (*Culex sollicitans*). New Jersey.

"Type specimen.—Collection U. S. P. H. & M. H. S., No.

9401, in poor condition; collected by Dr. John B. Smith, New Brunswick, N. J.

"In the summer of 1889 I collected a number of *Agamomermis* sp., from mosquitoes of the species *Culex nemoralis,* taken in the vicinity of Leipzig, Saxony. Whether they were identical with the present form I am unable to state. The interesting fact may be mentioned, however, that the Leipzig *Agamomermis* was distinctly injurious to the mosquitoes. It was found in the abdominal cavity of larvæ, pupæ, and adults, so that infection must have taken place in the water, namely, in the larva and pupal stages of the *Culex.* The infested insects were very sluggish in their movements and could usually be recognized as diseased. Many of them died from the effects of the parasite, and the ovaries of infected females were under-developed. Professor Leukart informed me at that time that he had frequently found *Culex nemoralis* infected with this worm, and that during the years that the worms were most common the mosquitoes seemed to be less numerous.

"These cases represent interesting instances in nature, where a pest is subject to other pests, which tend to hold the former in check.

"At least two other species of *Mermis* should be placed in the collective group *Agamomermis,* namely, *Agamomermis gammari* (von Linstow, 1892), parasitic in *Gammarus pulex,* and *A. sialidis* (von Linstow, 1892), parasitic in *Sialis lutaria.*

"At a time when mosquitoes are subject to such careful study, because of the important relations they bear to public health, especially in connection with malaria, yellow fever, etc., it is of interest to determine what parasites naturally infest them. This determination has its practical as well as its scientific value, for it enables us to eliminate certain nonpathogenic parasitic organisms from the life cycle of pathogenic organisms, stages of which may be found in mosquitoes. It further has its direct practical bearing in that the parasites of mosquitoes may multiply to such an extent as to become important factors in killing the insects, or at least rendering them less fertile.

"Quite recently several parasites have been described for the Culicidæ. Ross (1895) has found intestinal gregarines in mosquito larvæ in India. Perroncito (1899) has found a filamentous phytoparasite in Anopheles collected near Turin, Italy. Laveran (1902) has described a pathogenic yeast in the abdominal cavity of *Anopheles maculipennis* collected in Spain, and he reports various Acarines as external parasites of the Culicidæ. Leger (1902) has described a parasitic flagellate (*Crithidia fasciculata*) in the intestine of the adult female of *Anopheles macu-*

lipennis. Herbert Johnson (1902) has described a sporozoon as infecting about 8 per cent. of the females of *Anopheles maculipennis* collected in a certain locality in Massachusetts in which tertian malaria is endemic. Martirano (1901) has described a minute trematode (*Agamodistomum Martiranoi*, Stiles, 1903 [new name]) found in the body cavity of *Anopheles claviger* (= *A. maculipennis*) taken in Italy. G. W. Mueller found an undetermined sporozoon of the genus Glugea in *Culex*."

Agamomermis culicis has thus far been found in the adult only, but no attempt has been made to locate it in either larva or pupa or anywhere outside the mosquito body.

Several times during the summer of 1902 while examining female *sollicitans* to determine the development of the ovaries, I observed what seemed to be an abnormal enlargement of the digestive tract; but having only one purpose in view at that time I neglected this until on an occasion when I tore an entire abdomen apart, I found that it contained two worms and nothing else. These were the specimens that were later sent to Dr. Stiles and which served as the basis for his description. At about the time this description appeared in 1903, I had under examination a large series of *sollicitans* collected by Mr. Grossbeck at Barnegat Bay, and I was surprised to find a considerable number of these infested by the worms. This attracted attention to the subject, and after midsummer every lot of specimens that came in was examined. The result showed every collection from the Raritan River to Cape May to be more or less parasitized. But not a single infested specimen was found on the Newark or Elizabeth marshes.

Hundreds of specimens were collected and examined by Mr. Dickerson or myself; but in not a single instance was a parasite found. Furthermore, the percentage of infested specimens increased to the south, being much the highest at Cape May. Mr. Viereck's records on this point are interesting:

Date.	*Number of Specimens Taken.*	*Number Parasitized.*
June 25,	113	3
July 1,	148	15
" 10,	151	88
" 27,	137	10
" 31,	309	112
Sept. 13,	100	50
" 14,	100	39
" 17,	77	16
" 18,	62	2
" 21,	100	8
" 22,	100	1
" 25,	82	2

For some reason no large collections and examinations were made in August; but at that time my own examinations showed the largest percentage of parasites in material sent in from Ocean and Atlantic Counties.

That this parasite is a very material check to the multiplication of *Culex sollicitans* seems certain, for in no case where a parasitized specimen was examined were ovaries developed. In fact the worms, for there may be several in one insect, so completely fill the body cavity that there is room for nothing else. Of course the infested migrants are sterile in any case; but in the collections made by Mr. Viereck especial effort was made to get at the localities where oviposition was going on, and the collections containing the greatest percentage of parasitized specimens contained also the largest percentage of specimens with fully developed ova in those not infested. It need hardly be said, however, that the check was not sufficient to reduce the species appreciably even in those localities where it would seem to have been most effective; while the only localities where *sollicitans* was really rare in 1904 are those where the parasite does not occur at all. As to the effect upon the individual, it probably shortens life to some extent. It does not prevent migration because parasitized specimens have been taken far inland; nor does it prevent feeding, for I have killed specimens that have actually bitten me. In fact I sat for an hour one afternoon at Anglesea capturing such specimens as came to bite and examined for parasites, and found that nearly or quite half were infested. At New Brunswick the percentage was not so great; but was decidedly appreciable. As to whether the parasite can be practically employed I cannot say. Nothing is known of its life history nor where it passes its early stages and until this is worked out any statements would be mere guess work. The necessary studies must be made by one fully familiar with such animals and I have presented the matter to Surgeon General Wyman, of the Marine Hospital Service, as a subject meriting the attention of his department.

In the course of his work for this investigation in 1902, Dr. H. P. Johnson found the young of an intestinal worm in an *Anopheles* larva, and he suggests that it may bear some relation to this *Agamomermis;* but that seems scarcely possible, since the waters inhabited by the *Anopheles* never maintain *sollicitans* and *vice versa.* For the present the worm offers no prospect of a natural control of its host.

The Enemies of Larvæ.

While the adults are subject to numerous enemies and encounter dangers that kill off a large percentage of specimens before they have a chance to reproduce, the larva or wriggler faces yet greater dangers, and its chances to reach the adult stage are, on the whole, less than even. Numerous entire broods mature, of course, but on the other hand, numerous others are completely wiped out. The effect of weather conditions, which dry up or otherwise eliminate breeding places while swarming with larvæ, is elsewhere referred to, and this, after all, is the most effective general check.

Next to the weather comes disease; but of these diseases we know little. We know that sometimes almost every larva in a pool will die before it is mature, and I have had breeding jars in which it seemed impossible to bring any to the pupal condition. I place diseases as second in effect because they reach those cases of temporary pools where few if any other enemies can reach them.

Fish, which come in here, deserve separate consideration.

Pollywogs do not eat wrigglers except by accident, and this applies in general to those of both toads and frogs. It is possible that some of the other batrachians or reptilians may take them in one stage or another, but there is no evidence to that effect. Mr. Seal tested the pollywogs thoroughly and the conclusion that they are of no practical value is based upon his work.

His report of the experiments on the bull-frog is as follows: "A number of tadpoles of the bull-frog (*Rana pipiens* Latr.) were placed in a perfectly clean aquarium tank with clear water, in which were a large number of mosquito larvæ; but the tadpoles were not detected in eating any of them. The experiment was repeated and carried to the extent of depriving the tadpoles of all food for several weeks; but they were not even then seen to eat anv of the larvæ. They do eat small crustaceans like *Daphnia*. They do not seek for them, but suck them in if they happen to come within range of their suction. The mouth of the tadpole is very small and adapted to sucking, and it is possible that the spines in mosquito larvæ are offensive to them. As the tadpole of *Rana pipiens* is the largest and most voracious species, it is probable that there is no tadpole that is destructive to mosquito larvæ."

Some of the shore birds eat wrigglers in considerable quantities. Mr. Viereck sent me the stomachs of a ring-necked plover (*Ægialitis semipalmata*), of a least sand piper (*Fringa minu-*

tilla) and of a semi-palmated sand piper (*Eremetes semipalmata*), and all of these had eaten *sollicitans* larvæ in some numbers; the plover most of all. There was no especial difficulty in identifying the wriggler remnants from the head and anal siphon, which, being chitinous, were not digested. The number of specimens examined is insufficient to serve as a basis for positive statements, but it seems likely that many larvæ are devoured by the marsh birds.

The larvæ of dragon flies have been known as enemies to the wrigglers for ages, and they are as little entitled to credit for effective work as are the adults. They are bottom feeders, as a rule, and usually way below the range of even *Culex*, while *Anopheles* is in no danger from them whatever. On the salt marsh *Micrathyria berenice* is often very common, and I im-

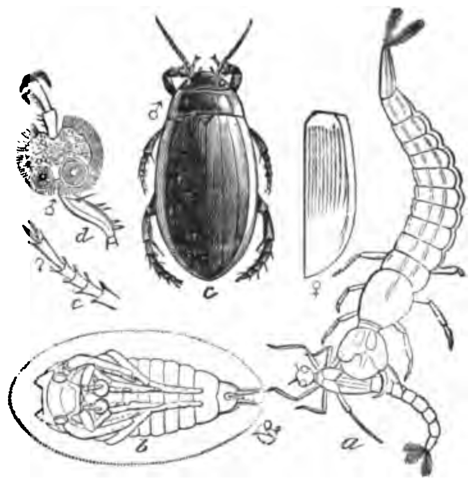

Figure 19.

A diving beetle, *Dytiscus marginalis*. *a*, larva, or water tiger devouring an agrion larva; *b*, pupa; *c*, male beetle, with wing cover of female at side; *d*, anterior tarsus of male, enlarged; *e*, tarsus of female. (After Riley.)

pressed upon Mr. Viereck the desirability of learning its relation to *sollicitans* and other marsh wrigglers. His report is that the larvæ are found in comparatively fresh salt water in the naturally-drained sedge marsh; never in stagnant breeding pools.

I have frequently found larvæ of dragon flies associated with an abundance of wrigglers, but, as a rule, there are few mosquito larvæ in those places where the others are most commonly found, their absence being due to other causes. It is not intended to say that dragon fly larvæ do not eat wrigglers as op-

portunity offers; simply that they do not form an important check.

On the other hand, the larvæ of the Dytiscids, or diving beetles, also called water tigers, are among the greatest enemies of mosquito life, and I am inclined to attribute the comparative freedom from mosquitoes in the hilly section of the State very largely to these insects. Dr. Johnson records an instance of their effectiveness in his contribution to the report of 1902.

"My observations were mainly confined to the 'water tiger,' or larva of the large water beetle, Dytiscus. The ability of this voracious creature to clear a pool of larvæ was demonstrated in the laboratory by several captive water tigers, all of them young ones, about a centimeter (less than half an inch) in length, which created havoc in some of the jars containing *Culex* larvæ.

"An out-door demonstration was afforded by a small pool about half a mile south of the North Arlington railway station, between Schuyler avenue and the meadows. To all appearances this pool, which was barely ten feet across in July and gradually diminished during the summer, possessed every condition for the breeding of mosquitoes in great numbers. In contained no fish and few water insects, with the exception of the Dytiscus larvæ, which seemed quite abundant. On July 26th, when first visited, the pool was thoroughly examined, but yielded very few larvæ of *Culex* and only two or three of *Anopheles*.

"The pool was visited again early in August, but no larvæ were found; again August 18th, when a very few *Culex* were obtained. In order to determine whether the water was incapable of supporting larvæ, ten large and medium-sized *Anopheles* larvæ were placed in a sample of it brought to the Laboratory. The next morning there were only eight. The loss of two was accounted for by the presence of a very small water tiger, which had been accidentally left in the jar, and at the moment of discovery had a larva in his jaws. After removal of the enemy, seven of the larvæ completed their development, and all had pupated on the 25th, thus proving that the water was by no means unsuitable for the development of *Anopheles*. The pool was visited again September 6th. Both *Culex* and *Anopheles* larvæ were found in fair abundance, but no *Dytiscus* larvæ were seen. The absence of the voracious water tigers, owing presumably to metamorphosis, seems the most plausible explanation of the great increase in the number of mosquito larvæ."

No one who has not actually seen these tigers at work can form any idea of their voracity. They rarely seem to be at rest, and when they do it is usually more a waiting for the approach of

their prey. Nothing seems to satisfy their hunger, and I lost a fine specimen, which I had hoped to carry to maturity, because the food supply once failed to last over night. Mr. Viereck noted specimens in one of his experiment ponds, and in confinement one good-sized example killed or devoured 434 wrigglers in two days. They are quite as effective as fish during their period of activity; but in very early spring and in late summer, when the species is in either the egg or pupal stage, the mosquito larvæ have a chance to recover somewhat. The adult beetles, while they are also predatory, are not nearly so voracious as the larvæ.

Anopheles as well as *Culex* fall victim to the water tigers, and where these are abundant, as they usually are in a hilly country with plenty of springs and running water, mosquitoes stand very little chance. In a flat country where temporary pools formed by rains are more numerous and springs less plentiful the Dytiscids are less numerous and hence less effective as a control.

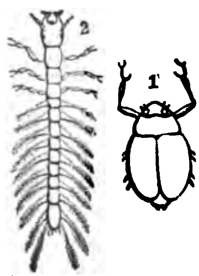

Figure 20.

A whirligig beetle (1), and its larva (2), natural size.

The whirligig beetles or *Gyrinidæ* are also great mosquito enemies and no *Anopheles* larva has a chance in any bit of water inhabited by them. They are found along the edges of ponds and larger permanent bodies of water; in the eddies of larger streams and sometimes in broad and rather rapid ditches. They are black or bluish bronzed in color and by their habit of circling about in swarms are readily recognized. Their surface habit and their tendency to get near the edges make them especially dangerous to *Anopheles* larvæ, which absolutely fail to maintain themselves within the range of these beetles. Their larvæ are also predatory; but little is known of them and none have been under direct observation by me. In ponds with shallow margins with grass that bars the beetles but not the *Anopheles* larvæ, a little trimming of the edges is sometimes all that is necessary to convert a source of danger into a safe area.

These seem to be the only beetles that have any decided effect in controlling mosquito larvæ and, while the water tigers are not particular as to the kind of place in which they breed, yet it must be reasonably permanent and they prefer it clean. They occur, however, in the brackish pools in the salt marshes. The whirligig beetles are useful only on large bodies of clean water; but their influence on the development of *Anopheles* is very decided. Neither of the groups reach the breeders in temporary rain-water pools nor those that live in foul water.

Figure 21.

A Water-boatman; Notonecta species.

Among the water bugs there are several species that form effective checks to mosquito breeding. Nearly all the predatory species will take mosquito larvæ and, usually, where the back-

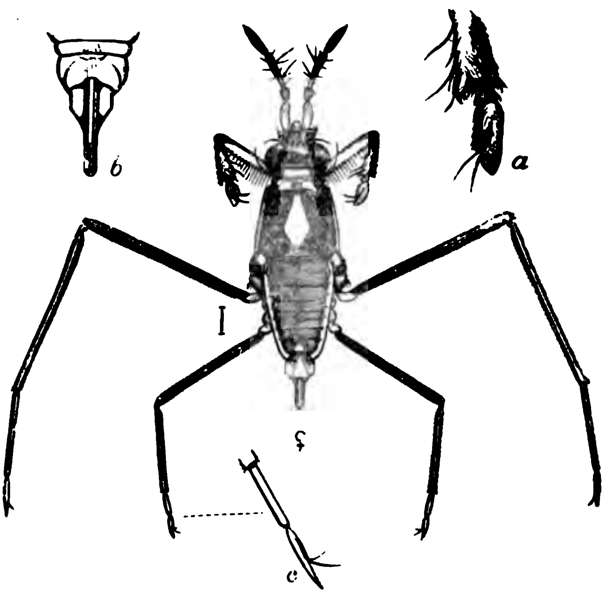

Figure 22.

A Water-strider, *Rheumatobates rileyi*, female. *a*, anterior tarsus; *b*, ovipositor; *c*, posterior tarsus, all much enlarged. (From "Insect Life," U. S. Dept. Agric.)

swimmers (*Notonecta*) and water-boatmen are common, wrigglers are scarce. These insects are usually plentiful where the duck-weed occurs and help to clear those parts of the ponds which the plant does not cover.

The water striders or skaters get all their food on the surface and I have never seen *Anopheles* larvæ where these insects occurred in numbers.

The water scorpions (*Nepa* and *Ranatra*) are curious bugs with either a narrow or a very flattened body and long slender legs. They live in the shallow water at the edges of quiet ponds and get their air supply through a slender tube that they extend to the surface of the water. They therefore walk around on the

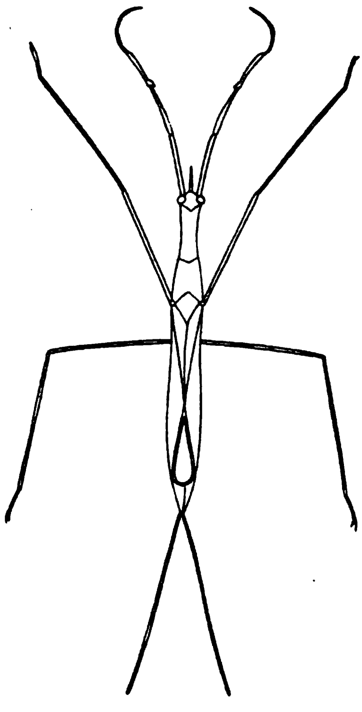

Figure 23.

A Water-scorpion, *Ranatra fusca*. (Re-drawn from Comstock.)

bottom with the long middle and hind legs, but keep in touch with the outer air by means of this breathing tube. The fore-legs are developed into a pair of grasping organs with which they capture their prey and bring it within reach of the short, sharp-pointed beak. Mr. Viereck comments on these insects as follows:

"The early stages of *Ranatra fusca* were destructive to wrig-

lers. With their raptorial legs they nip the larva near the breathing tube, then either drop or suck it. Quite a number were nipped and dropped and, once dropped, they rose no more. Pupæ, both of *Anopheles* and *Culex,* were expert in evading the grasp and were not readily caught. In less than an hour three *Ranatra* killed and sucked ninety-eight larvæ. It is a question whether *Ranatra* would be useful in stagnant pools, because the specimens used in the experiment could only be found in the clear water of a lily pond where, no doubt, they controlled the *Anopheles;* but when put into the stagnant water which *sollicitans* inhabits, they died."

What Mr. Viereck says in the last sentence expresses the practical limitation of the usefulness of all the insect enemies of mosquito larvæ; they do not inhabit the temporary pools formed by rains, overflows, tides or in other manners. Their life period is too long to admit of their using such places, and in them the wrigglers have the opportunity to develop undisturbed. It explains also why permanent bodies of water are relatively safe, and why even a country with plenty of brooks and ponds may be practically mosquito free.

So far as our present knowledge goes, we can make no practical use of these insect enemies as against the pestiferous species. All that we can do is to make natural conditions as favorable for them as possible.

This account of the natural enemies would be incomplete were I to omit the mosquito enemies of the mosquitoes. The larva of *Psorophora ciliata,* which is our largest species, feeds on other wrigglers exclusively, and is feeding constantly. A dozen of these specimens will clean out a jar containing a hundred examples of *pipiens* in less than twenty-four hours, and will be ready to eat each other if the stock is not promptly renewed. Usually, when a pool contains any number of large *Psorophora* larvæ the *Culex* are few and become daily less. To be sure the adult *Psorophora* also bites, but every such adult has prevented the development of at least 100 *Culex,* hence we can forgive something.

The species of *Corethra* which do not bite, are also predatory in character and prey upon mosquito larvæ, reducing them to a minimum in places where they occur. Unfortunately they are local and sometimes very rare.

The plant enemies, duckweed (*Lemna*) and the green thread-like *Spirogyra,* have been referred to in another connection and their method of checking mosquito development has been described.

Fish versus Mosquito Larvæ.

Of all the natural enemies of mosquito larvæ, fish are the most important from the practical standpoint because they can be transported to places where they are needed, because they will stay where put and because they live throughout the season.

In order to determine just which of our New Jersey species are effective I intrusted the general subject to Mr. William P. Seal, of Delair, New Jersey, because of his experience in collecting, observing and studying these fish. Practical experiments were made by Mr. Seal in his tubs and ponds at Delair, and collecting trips to determine the presence of certain species were made to the Delaware, to Townsends Inlet and to Cape May. The reports on experiments and on the collections made are contained partly in letters, partly in a more formal list of important species.

But beside these, more systematic studies, experiments and observations were also made by Mr. Brehme, at Newark, and by Mr. Viereck, at Cape May. All these observations will be collated and each observer credited; but in general where no specific credit is given, Mr. Seal is quoted. Most of the strictly descriptive matter is from Dr. Tarleton H. Bean's "Fishes of New York."

"The number of species of fish to be found in the waters of New Jersey where mosquitoes might be expected to breed, and which might be looked upon as destroyers of them, is comparatively small; but during the late spring, summer and fall, these few species abound in the young stages in almost incredible numbers. While the very young fry are incapable of devouring the full grown mosquito larvæ, they can devour them as they emerge from the egg, at which time they are very minute; so that it may be said that by the time a fish is a week or two old, it is prepared to take up the work of destruction. And it can be said with confidence, as a result of continued observation, that in the water to which these small species have free access, mosquitoes cannot propagate. An exception must be made of the genus *Anopheles* in places where there are dense masses of aquatic plants.

"It is rather a remarkable fact that of the large number of species of fish to be found in the waters of New Jersey, there should only be some nine or ten that can be considered as at all useful as mosquito destroyers; but when the wide distribution and abundance of these few species and the character of the water in which mosquitoes breed are taken into consideration it does not seem so strange. Fortunately the young of these few useful species abound in enormous numbers during the warm months in every accessible place where mosquitoes might breed.

It is only in the inaccessible places that the mosquito finds its opportunity.

"The fact that a species will devour mosquito larvæ when in confinement, is not evidence that they will do so under natural conditions. A fish in an aquarium is restricted in the amount and variety of its food. Its choice is very limited, and it is likely to eat anything offered to it, so that observations made in that way are of doubtful value.

"I am more and more satisfied that experiments made in tubs are of little value in determining the habits of fishes. It is impossible to approximate natural conditions in the matter of food. I would much sooner depend on observations made under absolutely natural conditions. It is easy enough to jump to conclusions from observations made under conditions partly or wholly unnatural; but that is not getting at the exact truth of the question.

"There are many questions involved in the use of fishes as a factor in the solution of the mosquito problem which can only be determined by experiment. The transfer is easy, but will they remain and multiply? Eel fry were transferred to the great lakes many years ago, and eels are caught there; but that is no evidence that they multiply. While on the Atlantic Coast the waters abound with young eels, none have been found in the great lakes. On the other hand, about a quarter of a million of shad fry were carried to the Pacific Ocean and planted and shad are now as abundant where there were none before, as they are in the Atlantic. Millions of whitefish fingerlings have been planted in the Potomac River and in certain lakes; but they have not accepted the conditions offered them or they have been overcome by natural enemies. At all events they disappeared.

"It is easy to theorize or to jump to conclusions, but in fish culture as in agricultural development there must be rational and patient investigation before there can be really effective work.

Gregarious Species of Active Habit Occurring in Salt or Brackish Waters.

"The common tide-water minnows, killies, killifish, mummies, mummichog, etc., are by reason of their enormous numbers undoubtedly instrumental in preventing mosquitoes from developing in such multitudes as to make human life unendurable along our marshy coasts and lowlands. Breeding principally in the shallow pools left on the mud flats by the receding tides, the young appear in the spring in enormous numbers and remain there until they attain a considerable growth—an inch and a half or two inches—when they begin to run in and out with the tide.

As the tide moves in over the marshes or flats, these fishes move with it in unbroken line like a heavy line of battle, feeding as they go. The chance of a mosquito larva escaping them is infinitesimal. Any waters to which these fishes have free access will be searched in vain for mosquito larva. An exception must always be made of places where there are dense masses of aquatic plants coming to the surface, over which, in fresh water, *Anopheles* will harbor. Unfortunately all the species of *Fundulus* which throng the coast and rivers of New Jersey attain a length of from four to six inches, and it is the young alone that can be depended on to penetrate in any great numbers to the furthest limits of tide flow."

No one can properly appreciate the importance of these little fish who has not seen the swarming mass of wrigglers in the salt pools containing none of them and the freedom of these where even a few killies are found. To be sure larvæ are sometimes found with the little fish; but then, either the larvæ were so numerous that the fish simply could not eat them all or the fish were so small that they could not manage the full grown larvæ.

An impressive example of their usefulness is cited by Mr. Brehme: In the morning at low water he crossed the Newark meadows to the shore and found all pools fairly swarming with larvæ and pupæ—millions upon millions. During the day the tide rose to an unusual height, covering the marshes almost to the highland. In the early evening on his return to the city, recrossing the marsh, he found killies in all the pools and larvæ and pupæ scarce. Next day on further examination he found the brood almost completely wiped out. Almost every little hole had one or more of the fish and the larvæ had disappeared.

In 1903 one of my cage experiments was spoilt in the same way. The cages were set just below the edge of the highland, but well beyond the reach of all ordinary tides. While the pools within the cage were fully stocked, the tide rose to an unusual height and fish found their way through the openings between sill and marsh into the cage itself. When the cage was next visited only the fish were left.

During 1904 tides ran low, and it was the absence of the usual overflows that permitted the marshes along the coast to develop the enormous first broods that flooded the country in May and June. Usually the bulk of that brood forms fish food. Besides, the winter of 1903-04 was so unusually severe that a very large percentage of the fish were killed off.

Several times during the seasons of 1903 and 1904 Mr. Brehme transferred killies from ditches to pools swarming with larvæ, and in every instance it was only a matter of hours before

the insects disappeared. This was done under so many conditions that no doubt exists of the fact that the mosquito larvæ are a normal food of the little fish.

More specific experiments were made by Mr. Viereck at Cape May. Two pools were selected early in June, each about three square yards and each containing by estimate about 20,000 wrigglers. Into one of these sixteen *Fundulus* were put, into the other fifteen *Cyprinodon*. The *Fundulus* did not find the water to their liking and devoted their energies to trying to get away. The water was very foul and stagnant and it was afterward found that these fish would not live under such conditions. *Cyprinodon* was less particular and in four days had devoured the majority of the larvæ—say 12,000 in four days, or 200 per day to each fish.

July 16th another experiment was made, and seventeen specimens of *Fundulus* ranging from two and one-half to three and one-half inches were put into a pool from two to three inches deep with a surface area of two square yards and containing nearly one thousand wrigglers. In half an hour more than 90 per cent. of the larvæ had disappeared and the fish were yet at work.

Then a trial was made of the comparative hardiness of *Cyprinodon* and *Fundulus* by placing both in tubs with an inadequate supply of water, and in this test *Fundulus* did better, *Cyprinodon* becoming asphyxiated first.

A further test was made July 18th, when four large pans were stocked, each with a large dipper full of well-grown larvæ. No. 1 was kept as a check; in No. 2, four small *Cyprinodon* were placed; in No. 3, six medium-sized *Cyprinodon* were put, and No. 4 received two medium-sized *Fundulus*. It was intended that each pan should contain about the same number of wrigglers, but they were not counted. Three days later few larvæ remained, the change to the pupal stage going on so rapidly that to prevent the issuance of adults the experiment was closed. Pan No. 1 now contained 832 larvæ and pupæ, and this was assumed as the number originally placed in each. Pan No. 2 contained 248 larvæ and pupæ, hence four small *Cyprinodon* had eaten 584 wrigglers. Pan No. 3 had no larvæ and pupæ, hence six medium-sized *Cyprinodon* had eaten 832 larvæ. Pan No. 4 had 133 larvæ and pupæ, hence two medium-sized *Fundulus* had eaten 699 wrigglers; surely an excellent record for the little fellows!

In the experimental ponds, brood 6 at Cape May developed toward the end of August and then they began to dry up. The fish which had bred in the ponds retreated to the deepest pools

and finally into the mud itself, where many of them died. But some survived until the ponds were refilled by rains, and these survivors effectually dealt with mosquito brood 7 as soon as it appeared. Not an adult was allowed to come to maturity.

Had these ponds been stocked with either *Fundulus* or *Cyprinodon* early in the season, and had a barrel been sunk in the deepest portion of each to furnish a retreat for the fish during the droughts, not a mosquito could possibly have hatched from them while millions did actually breed there.

The last paragraph refers to a suggestion made by Mr. Seal that, in pools of large area which are likely to dry up, a barrel be sunk in the deepest portion to serve as a retreat for the fish which would be killed off otherwise during the dry spell, leaving the pool in excellent shape for the wrigglers when rain refilled it. This suggestion is eminently practical and is a cheap way of dealing with many depressed areas which cannot be readily drained.

FUNDULUS MAJALIS.

Striped Killifish, May fish, Rock fish, Bass Killy.

This is the largest of the species, attaining a length of from six to eight inches and it ranges from Cape Cod to Florida. "The adults of this species do not go above salt or quite brackish water; nor do they leave the channels and spread over the flats and marshes as do *heteroclitus* and *diaphanus*. They move in schools and seem never to rest, going with the tide in the channels until it turns and then quickly moving out. This species has the least value as a destroyer of mosquito larvæ."

The sexes may be distinguished at once by their difference in color, the female having several narrow lateral stripes, while the male has distinct cross bands, varying from twelve to twenty in number. In the male the sides and upper parts are dark olivaceous; the sides are silvery, lower parts a beautiful yellowish green; the sides are also marked by a varying number of dark bands, the width of which varies also. In the female the lower parts are white, upper parts olivaceous, and along the sides is a median dark band and below this are two short, interrupted dark bars.

In winter it inhabits deep, muddy holes at the mouths of creeks. In captivity it is the least hardy of all the marine killifishes.

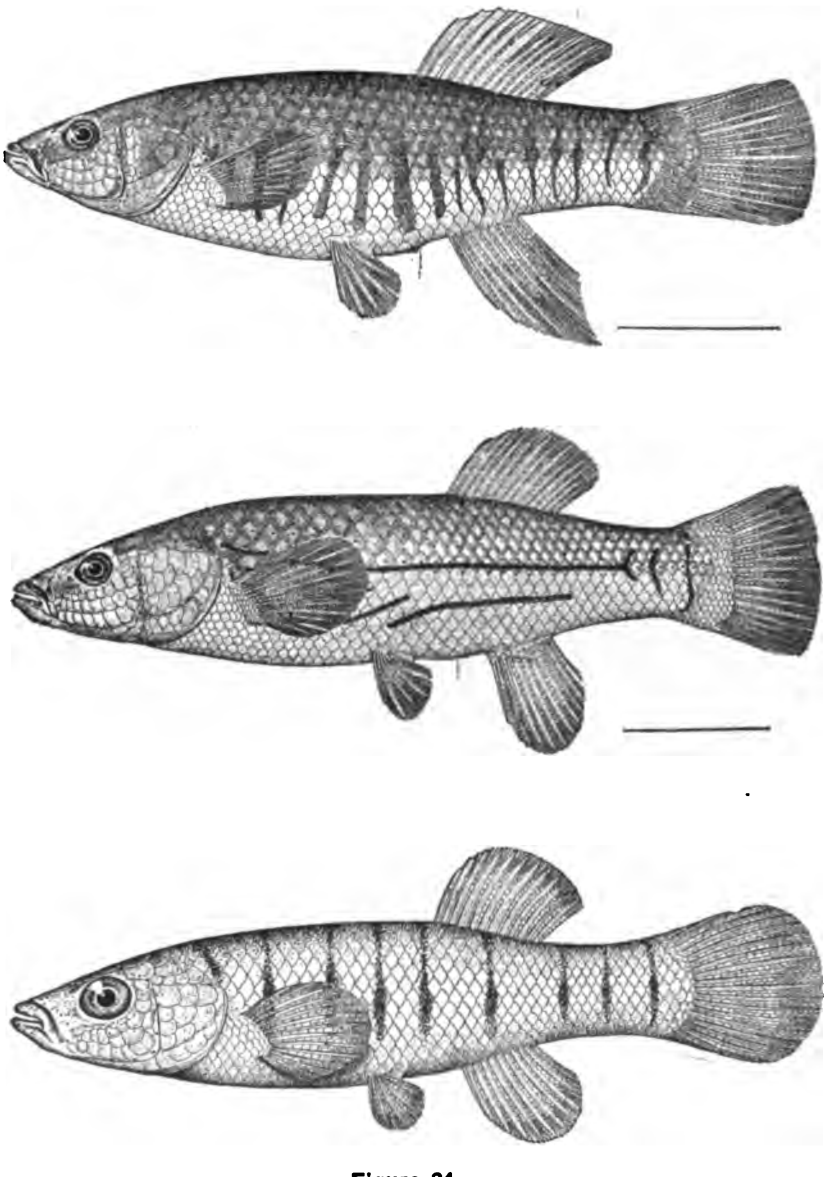

Figure 24.

Fundulus majalis: striped killifish. Male above; female central; yourg below. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

FUNDULUS HETEROCLITUS.

Common Killifish, Mud Fish, Mud-dabbler, Mummichog, Salt Water Minnow.

"The length of this species is given as three to six inches. The writer after handling thousands of them, principally from the Delaware, would consider one four and a half inches long to be very large. It is probable, however, that they are larger in the salt water. Its range is from the Coast of Maine to the Rio Grande, everywhere common in brackish waters, often burying itself in the mud in shallow lagoons. This species is abundant everywhere to the extreme limits of tide water. They are equally at home in salt or fresh water, the clearest water or the muddiest ditch or pool. They are not even averse to the filthiest sewage water, collecting in vast numbers at the mouths of sewers

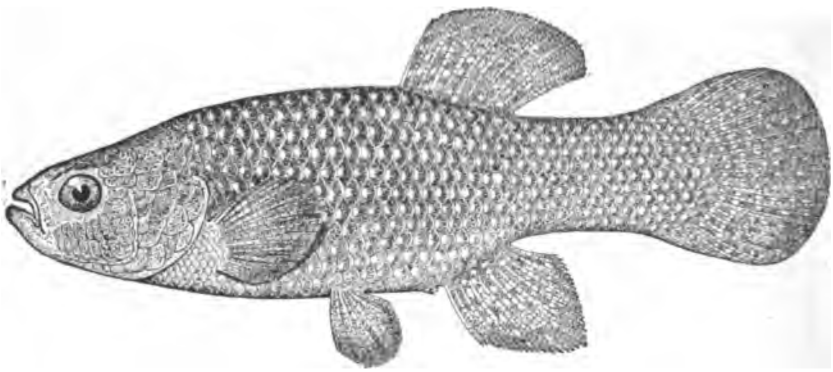

Figure 25.

Fundulus heteroclitus: the common killifish: male. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

at low tide. They will be found in the most insignificant and shallowest depressions on the flats or marshes, in ditches filled with reeds, spatterdocks or masses of submerged plants, and in muddy holes devoid of plants or other shelter. They will push through places where there is hardly enough water to cover them and find their way to the source of a tiny stream of water over rapids and perpendicular falls in a manner that would tax the credulity of one not familiar with the ways of fishes.

"In company with *diaphanus* they are to be found in the ditches and marsh holes along the Delaware River all through the winter and may be taken from under the ice in great numbers. In

winter they may be carried for hours without water, until the mouth is completely closed with a plug of ice and they are apparently dead; yet upon thawing out they will be as lively as ever. But, notwithstanding this apparent hardihood they in common with the others of this genus are difficult to hold in captivity in large numbers, as most anglers can testify. The common name of this species about Philadelphia is 'bullhead' or 'Bullhead minnow.' No doubt because of the very blunt head and snout.

"It is probably the most valuable species of *Fundulus* for the purpose of mosquito prevention, being a top feeder and a great forager. And if any one of the *Fundulus* will remain and multiply in land-locked waters it will be this species."

My personal experience is that in a one-quart fruit jar I have kept half-grown specimens for months, and in a cistern many years ago always had a supply of from ten to a dozen. While some died, of course, most of them lived a long time and even wintered, but never multiplied. There is no doubt that in water barrels and cisterns this species would flourish for the season at least.

The females are nearly uniformly olivaceous, lighter below. The males are dark greenish, with many narrow, irregular, silvery bars on the sides and the belly yellowish or orange. The sides are also more or less spotted with white or yellow.

FUNDULUS DIAPHANUS.

Fresh-water Killy.

The length of this species is given as about four inches, but five inches will be nearer the mark. Its range is given as Coast of Maine to Cape Hatteras, ascending streams to their fountain head; hence abundant in lakes throughout New York. It is the most graceful and active species of the genus *Fundulus* found in New Jersey waters. While having about the same range as *heteroclitus* its movements are confined more generally to the channels and currents, evidently preferring clear open water. The young mingle and move with those of *heteroclitus,* but as they grow larger they separate more and more. It may be set down as a rule that in places where *heteroclitus* are abundant, *diaphanus* will be scarce, and vice versa; indicating that they differ radically in their choice of conditions."

Dr. Bean in his "Fishes of New York," states that this species thrives better in aquariums than any other killy save *heterocli-*

tus. It becomes very tame in captivity, though always attacking the fins of other fishes. The species occurs in ponds on Long Island and Manhattan Island, and Mr. Wm. T. Davis, of Staten Island, writes that, "Here on Staten Island, in a pond in the Clove Valley, a mile or more from Salt Water, it has been common for many years. The little fish are born in the pond and never see salt water. I am quite sure this fish would be of use to you in the mosquito experiments."

Mr. Seal, however, questions the advisability of using this fish in inland waters because it would destroy the eggs and young of more valuable species which are by nature better adapted to land-locked or stagnant waters.

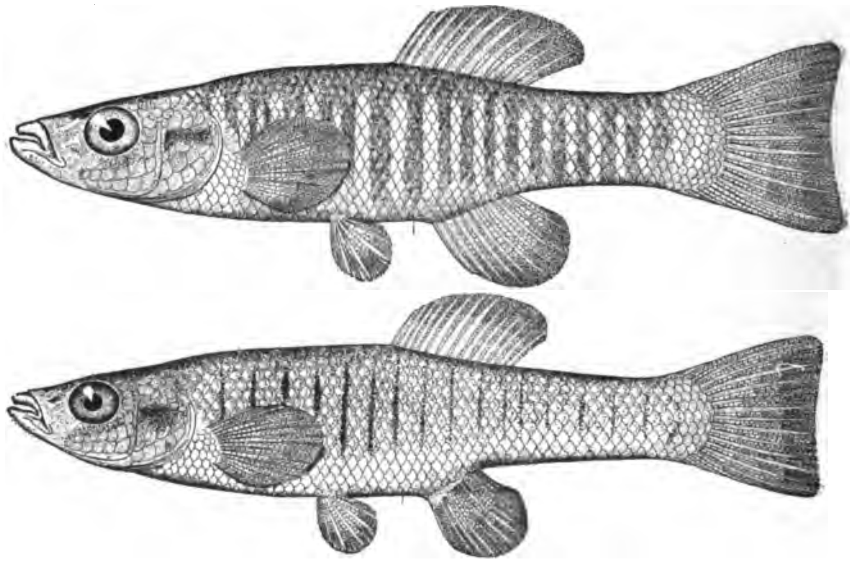

Figure 26.

Fundulus diaphanus: the fresh-water killy: male above; female below. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

This objection, however, would not apply where ponds are not already stocked, and for these, the species being a top feeder, might be useful.

This little fish differs from its allies in that it has the tail squarely cut off, not rounded. The females are olivaceous with silvery; sides traversed by fifteen to twenty-five narrow dark cross bands; fins pale. The males, at least in the breeding season, are pale olive with about twenty pearly white cross bands.

All these species are moderately slender, graceful fish, quick in motion, and with the mouth so situated as to be able to feed at the surface.

LUCANIA PARVA.

Rain-water Fish.

This is a very small species, ranging from one and a half to two inches in length, the body oblong, compressed, rather short and stout. The color in the males is olive or pale brown, with bluish reflections, the edges of the scales darker. The females have the fins pale olive, without black spot or edging. In life the body is almost transparent.

This is one of the less common species and does not seem to occur at all commonly on the more northern sections of the coast. Mr. Brehme has never found it near Newark, but has found it at Atlantic City. Mr. Seal has taken the species at Cape May as well as Atlantic City; but at Cape May Mr. Viereck found it

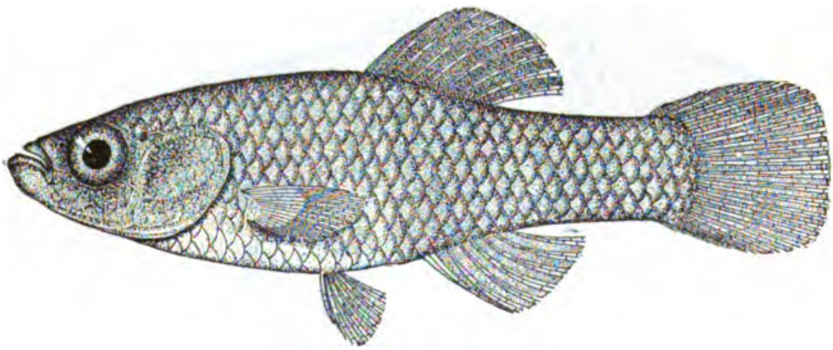

Figure 27.

Lucania parva: the rain-water fish. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

very local. Its movements are graceful, but it is not an active fish like *Fundulus* and is not a top feeder. It is not hardy and does not run over the marshes like the killies. No close collections have been made, so it is not known how far up the creeks and streams this species may extend.

CYPRINODON VARIEGATUS.

Sheepshead Minnow; Variegated Minnow; Pursy Minnow.

"This is the most beautiful species of the family *Pœciliidæ* that will be found on the New Jersey Coast, the males being very brightly colored. Its range is given as Cape Cod to the Rio

Grande, in brackish waters, entering streams. It attains a length of three inches for the males and two inches for the females. It is not an active fish. Like *Lucania,* it collects in great numbers in pools and remains quiet during the ebb of the tide, becoming active as it flows in."

This is a chunky, pot-bellied little species, totally different from the species previously described, its appearance indicating a much less active existence. Dr. Bean remarks that it is "one of the best of its family for aquarium purposes, as it thrives and breeds in captivity; the young, however, may be eaten by

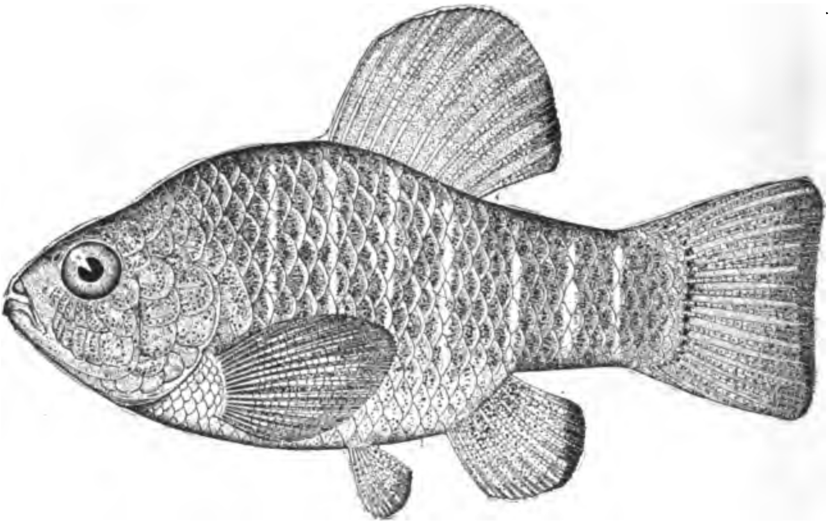

Figure 28.

Cyprinodon variegatus: the sheepshead minnow. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

their parents. Mr. Viereck has determined its usefulness as a feeder upon mosquito larvæ, so it is quite possible that this may be a better fish for cisterns than *Fundulus.* The matter is worthy of experiment and there would be no difficulty in getting material.

"The stumpy, pot-bellied body of *Cyprinodon* is evidence of its more sluggish and omnivorous habits. And *Lucania,* though slender bodied, appears to be generally found in its company or under similar conditions. They will live in ditches and pools so filthy and foul with noxious gases as to be beyond belief. We found the stomachs and intestines of *Cyprinodon* to be filled with the mud of the bottom slime, conferva, mud, etc. They were puffed out as though ready to spawn."

GAMBUSIA AFFINIS.

Top-minnow.

"A viviparous species, attaining a length of about one and one-half to two inches. Its range is given as 'Delaware to Mexico,' but it may possibly be found on the coast of New Jersey. It is, at all events, easily obtained and transported.

"This is a very active species, being constantly in motion, a

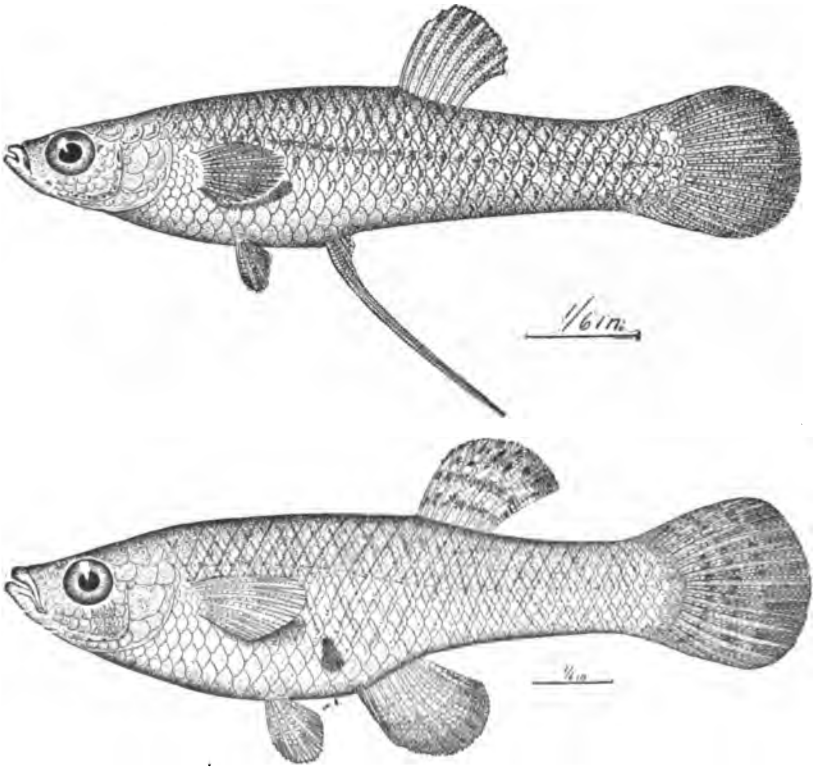

Figure 29.

Gambusia affinis: the top-minnow: male above, female below. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

top feeder, and penetrates to the shallowest edges of the waters it inhabits. Being very small and slender, it easily glides over masses of aquatic plants and penetrates among them as no other fish does. It has been tested in small ponds and tubs during two summers and no mosquito larvæ make their appearance when

they are present, while *Anopheles* will appear in similar places where there are gold and other fish. Two of them will keep a tub clear of mosquitoes. They breed rapidly, bringing forth young several times in a season. When extruded, they are many times larger than the newly hatched gold fish and, having no umbilical sac, they begin to prey at once."

Among the fishes of New Jersey there is none that quite fills the place of this *Gambusia* for choked-up streams and swampy areas. It lives in fresh water as readily as it does in brackish, and does well in captivity or restricted areas generally. Its ability to get along in the merest film of water over a lily leaf, where *Anopheles* larvæ find safety from other fish, gives it a field of usefulness whose importance cannot be over-estimated. It was deemed important then to make certain, if possible, that the species did not actually exist along our coast line. Mr. Seal asserts that New York dealers have the species, often in large numbers in late summer, and that they are supposed to come from Long Island. The species is not included in Dr. Bean's work on the fishes of New York; but the conditions along our South Jersey shores are not unlike those much further South, and Mr. Seal believed that there was at least a good chance of finding the species. In August, 1903, therefore, he visited the shores along Absecon, Two-Mile Beach and Cape May. All the species already mentioned were here taken, and several others which are of no importance for our present purpose; but there was no trace of *Gambusia*. Yet Mr. Seal believes it may be in some of the creeks or rivers emptying into the Delaware Bay; but that point could not be investigated. The species will live in New Jersey, during the summer at least, and there seems to be no good reason why it should not be able to winter, as well. But to make the experiment properly required more money than I could spare from the appropriation, hence no attempt was made to secure an actual stocking of any stream.

Mr. Seal writes on this point: "The sea coast of New Jersey is, in my opinion, amply protected so far as fishes are concerned. I do not think you can improve on *Fundulus, Cyprinodon* and *Lucania* for the marshes of the coast. And as for the shore waters of the Delaware and its open tributaries, *Fundulus* will do the work. But there are thousands of 'branches' which connect with the creeks by sluices, and which are sluggish and dense with plants.

"This, therefore, is a separate problem from that of the coastal waters proper.

"It is my belief that it would be wise to place *Gambusia* in the head water 'branches' of the cedar-swamp fed streams, such as

the Rancocas, Big and Little Egg Harbors and others, and from these small spring-fed tributaries, many of which never freeze over, let them spread down the streams. I am satisfied that if we go about it right, there will be no trouble in introducing them to such waters; and in thinking the matter over in connection with such places as I know of as being suitable, I conclude that spring would be much the best time for the experiment, for the reason that pike and other predaceous fishes collect about the deep holes and spring places in winter, and *Gambusia* would have little chance for escape, whereas in the spring they could find protection among the plants and in the shallows where the others could not reach them. Another consideration is that in fall we should be submitting a few thousands to new and unfavorable conditions at the most unlikely time of the year, whereas if we put the same number out in the spring, by fall we can reasonably expect that there will be tens of thousands, thoroughly familiar with and adapted to the waters in which they began life, and, having known no other, there will be no question except that of temperature involved.

"I have seen *Gambusia* collected in vast numbers where there was thin ice, at Cape Charles, Va., and I have no doubt they passed the winter in those places, where probably the ice was at times two or three inches thick, or even more."

This would be an ideal species to introduce into ornamental ponds in which aquatic vegetation forms an important feature. Such ponds having no fish save those which are placed in it would allow this little species to develop unchecked and would absolutely prevent all danger of mosquito breeding.

Should this work on the mosquito problem be continued with a sufficient appropriation, a careful and systematic attempt to introduce and acclimate this little fish will be made.

Gregarious Species of Active Habit Inhabiting Fresh Water.

ABRAMIS CHRYSOLEUCAS.

Roach, Shiner, Bream.

"This is one of the most abundant and widely distributed of our smaller fishes. It is gregarious in habit and very prolific. Though a timid fish, it is very active and one of the most useful for controlling mosquito larvæ. Schools of them will be constantly moving over certain areas which constitute their ranges. Though they do not penetrate dense masses of plants, they pass

among and through them wherever openings occur, feeding as they go. They are found in both running and stagnant water. Notwithstanding that it is the favorite food of game and other predaceous fishes, it is everywhere abundant."

Dr. Bean states that "the roach grows to a length of one foot and a weight of one and one-half pounds. It frequents sluggish waters, abounding in bayous and weedy ponds as well as in tidal waters. According to Jordan, its favorite shelter is the yellow pond lily. It may be readily distinguished by its shape, which resembles that of the shad, and by the very long anal fin, which contains from fourteen to seventeen rays. The colors of this fish are greenish above, and the sides silvery, with golden reflections. Fins usually yellowish; lower fins scarlet in breeding males."

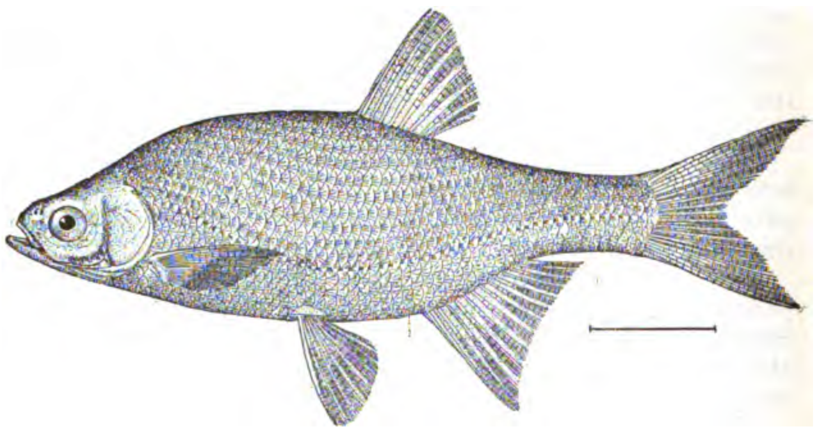

Figure 30.

Abramis chrysoleucas: Roach or Shiner. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

That this fish in its younger stages at least is an excellent mosquito control is proved by observing that wherever it occurs mosquito larvæ are absent, except in places which it cannot reach. Experimentally it was proved by introducing a specimen into a water barrel swarming with wrigglers. In a couple of days it had devoured practically all the larvæ, and was then transferred to another barrel, where its work was equally thorough if a little slower. As against *Culex* this species is excellent, as against *Anopheles* and some other species that favor grassy areas it is of less account. Mr. Seal seems to consider it the only fresh water minnow worthy of attention in this connection. He writes: "There are a number of other *Cyprinoids,* large and

small, which rarely make their way in any stage of their lives into the places where mosquito larvæ breed, and therefore exert no beneficial influence in this direction. Among them are the common gold fish, the European or food carp, the chubsucker, silverdace, etc."

Concerning the carp, it may be said here that its presence in a pond is a disadvantage rather than otherwise to the smaller species. It eats their spawn and stirs up the bottom mud so that the eggs are covered and choked. Being a bottom feeder, like the catfish, the species is of no value as a mosquito control. The gold fish stands on a somewhat different footing.

CARASSIUS AURATUS.

The Common Gold Fish.

"It is a well known fact that gold fish in aquaria will eat mosquito larvæ with avidity. The amateur breeders of fine gold fish about Philadelphia often breed mosquito larvæ as food for their stock. But the conclusion should not be hastily accepted that the gold fish will prove a wholly satisfactory destroyer of mosquito larvæ. In fact, while it is no doubt of some value in this respect, it is of lethargic habit as well as largely herbivorous and not as useful as many other species."

Nevertheless the gold fish has its field of usefulness in fountain basins and in small artificial ponds not too much overgrown. In such places where it can reach the very edge of the water it serves very well. Even in cisterns it thrives, and in such a place nothing in the way of a wriggler can escape it.

The gold fish is an introduced species which has escaped from captivity and spread into ponds and streams in many places. Under such conditions it loses its red or "golden" color and becomes a silver fish. Dr. Bean quotes as follows: "In many of our streams and ponds the gold fish has run wild, and hundreds of the olivaceous type will be secured to one of a red color. In the fauna of the moraine ponds and in quarry holes, the gold fish stands first. It will breed in foul water where only cat-fish and dog-fish (*Umbra*) can be found."

Solitary Species of Sluggish Habit Inhabiting Fresh Water.

EUPOMOTIS GIBBOSUS.

Common Sunfish; Sunny; Pumpkin Seed.

"This is the most abundant and widely distributed among the sunfishes. It is generally found among or near aquatic plants where there is such shelter; but also often found in abundance in open ponds and the merest puddles affording no protection. This is undoubtedly the most useful species of sunfish as a destroyer of mosquito larvæ."

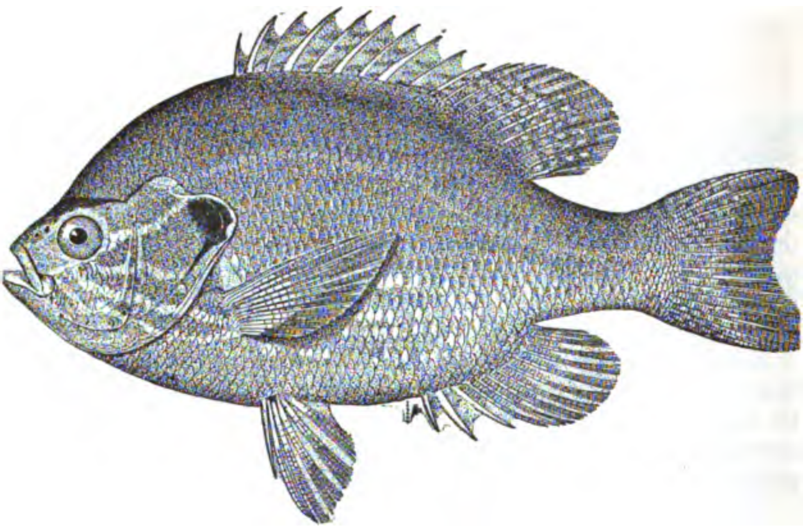

Figure 31.

Eupomotis gibbosus: the common Sunfish. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

It is this species more than any other that keeps the ditches and streams in cranberry bogs free from wrigglers. I have searched these ditches again and again in vain, except where they were practically dry, and only a few pockets were left. Wherever there was any appreciable quantity of water this species was found. I have also seen, where the water was drawn from a flooded area, thousands of the sunfishes left exposed on the mud—a population that had not been suspected, but which, without doubt, had rendered good service in preventing that area

from breeding mosquitoes. They will run up a little stream to its very head and will manage to get into ponds and pools where they have any kind of connection with a stream.

Unfortunately the shape of the sunfish is such that it cannot get into shallow, grass grown margins, nor over water-covered leaves where *Anopheles* find shelter; therefore sunfish and *Anopheles* may co-exist.

The species grows to a length of eight inches and is one of our most brilliant forms. The upper parts are greenish olive with a bluish tinge, the sides profusely spotted with orange, the belly and lower fins orange and the dorsal and caudal fins bluish with orange spots. The cheeks are orange with undulating blue stripes; the opercular flap is black, emarginated behind and underneath with bright scarlet.

It need hardly be said that there is no difficulty in introducing sunfishes into almost any body of water; but it should be said that they are predatory and will attack almost any other small species that may be in the same pond. Therefore when a pond has been stocked with roach, no sunfish should be added. But sunfish and *Fundulus* would go well together.

EUNEACANTHUS OBESUS.

Banded Sunfish.

"This is a small species not exceeding three inches in length, harboring altogether among plants; never found in open water. Quite widely distributed, but never nearly so abundant as the preceding."

Dr. Bean says: "It is olive green in color, with five to eight dark cross-bars intermingled with golden or purplish spots. There are lines and bars also on the cheeks. The flap on the opercle contains a velvety black spot with a purple border. Below the eye is a dark bar. This is a beautiful little species, but has no economic importance.

"In our vicinity it inhabits the entire Hackensack Valley, preferring quiet, weedy places. For the aquarium it is the most desirable of all the sunfishes, as well on account of its hardiness as of its harmless nature."

EUNEACANTHUS GLORIOSUS.

Blue-spotted Sunfish.

"About the same size as *obesus* and with habits similar. They are often found together, always among plants."

Dr. Bean says: "In spirits the color is brownish; about seven or eight rows of scales below the lateral line with pearly blotches forming interrupted stripes; a dark band under the eye; the dorsal, anal and caudal profusely spotted with roundish, pearly spots. Young individuals are obscurely banded. In life the spots of the male are blue, and the fins are higher than in the female; the opercle bears a pearly blue spot."

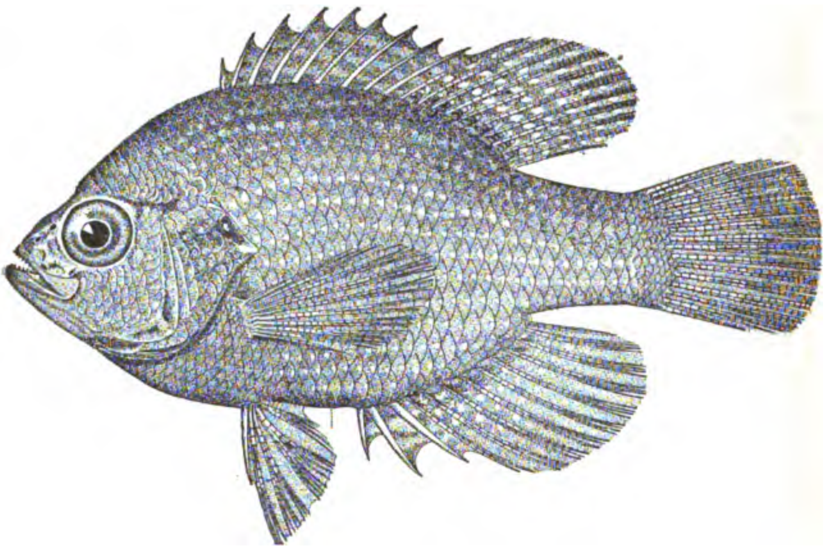

Figure 32.

Eneacanthus gloriosus: blue spotted sunfish. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

Mr. Seal adds that: "There are many more species of sunfish in New Jersey, but the three above mentioned are the only ones that are widely distributed and abundant in waters where mosquitoes might be expected to breed. Another small species, *Mesoganisteus chætodar,* is extremely local and nowhere so abundant as the others." The mud sunfish, *Acantharchus pomotis*, prefers muddy water and may even lie imbedded in the mud. It is shy, seclusive and nocturnal in habit.

Species which have been Suggested as Possible Mosquito Destroyers; but which are of Practically no Value.

APELTES QUADRACUS.

Four-spined Stickleback.

"Sticklebacks have been mentioned as possible destroyers of mosquito larvæ. There is but one species to be found above brackish water in the Delaware River, the four-spined *Apeltes quadracus*. This species is very small, the male attaining a length of about one inch, and the female about one and three-quarter inches. It is a bottom feeder, hiding under and among aquatic plants, logs, sticks or any sort of debris on the bottom of ditches

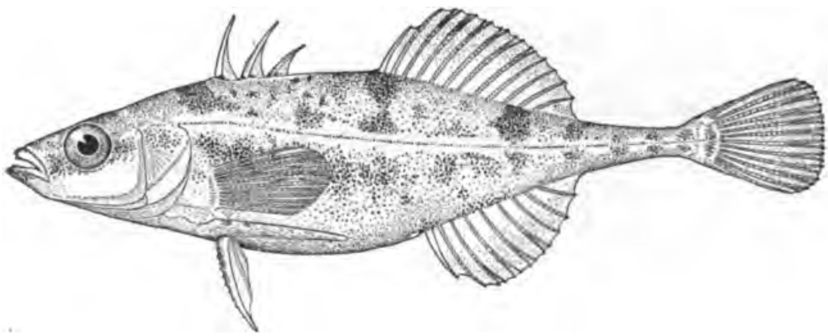

Figure 33.

Apeltes quadracus: 4-spined stickleback. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

and pools along the shores of the Delaware and its tributaries. It is undoubtedly useless for the desired purpose and should not be further considered. The other species rarely go above brackish water and are seldom found out of the deeper channels."

UMBRA PYGMÆA.

Striped Mud Minnow; Eastern Mud Minnow.

"Widely distributed but not abundant anywhere; solitary, sluggish; always among plants. Not worthy of consideration in connection with the mosquito problem."

The species grows to a length of about five inches and is easily known by the prominent black bar just behind the end of the

tail. It is sometimes called dog-fish, like its ally (*limi*) from the north and west. It is called "mud minnow" from its habit of burrowing into the soft bottom when the water dries out, and it is able to maintain life in such position for a considerable period. It is found in the more permanent woodland pools and does feed upon mosquito larvæ to some extent, as was demonstrated when a small specimen was accidentally collected with a lot of wrigglers. The bottle was left standing over night and next morning little more than the fish remained. On the other hand, in these very pools known to be inhabited by these minnows, there are always plenty of larvæ to be found, so that Mr. Seal is probably quite right in his conclusion that the species is unworthy of consideration in this connection.

APHREDODERUS SAYANUS.

Pirate Perch.

"Nowhere abundant; sluggish; not widely distributed; always among plants; a useless species."

Dr. Bean states that the fish grows to a length of four inches, that it is very voracious, feeds at night, inhabits sluggish streams and ponds in the shelter of aquatic plants and that nothing more is recorded of its habits.

ERIMYZON SUCCETTA.

Chub-sucker; Creek fish.

"Abundant in ponds; has the sucker mouth; is a bottom feeder; useless for mosquitoes."

The form that occurs in New Jersey is that which has been named *oblongus* and grows to the length of a foot. The food, according to Bean, consists chiefly of minute crustaceans, insect larvæ and aquatic plants. The larvæ referred to are probably those of the May-flies and other Neuropterous types, though, no doubt, mosquito wrigglers would be accepted did they come within reach.

Mr. Seal at the end of his report presents a few general conclusions in which I desire to express my hearty concurrence. They are:

"That as destroyers of *Anopheles* larvæ in ornamental ponds containing much aquatic vegetation, only the top minnow is of value.

"As destroyers of all other species in natural waters, all fishes are of some value.

"There is no necessity for stocking natural waters with fish as few mosquitoes are developed in such as are already inhabited by them.

"The presence of bass, sunfish, pike and other predaceous species is prejudicial to an abundance of the smaller and insect feeding kinds.

"Much the larger proportion of mosquitoes is developed in insignificant places uninhabited by fishes.

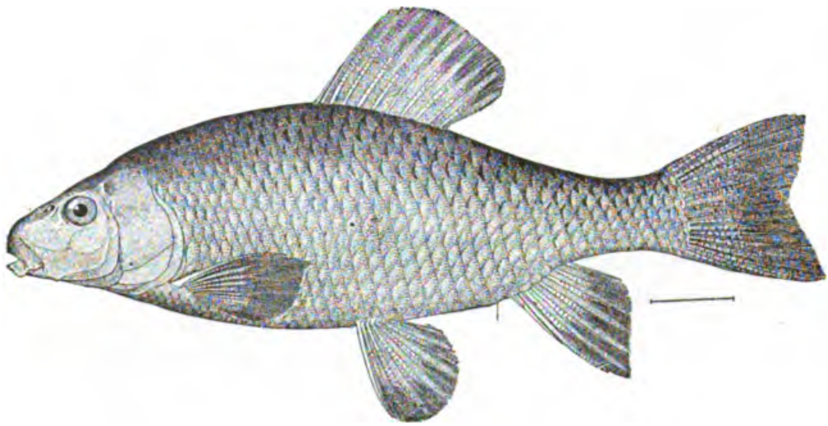

Figure 34.

Erimyzon succetta: the Chub-sucker. (From Jordan & Evermann, Bull. 47, U. S. Nat. Mus.)

"The number of mosquitoes developing where there is an abundance of aquatic insects and their larvæ is very small. The great irruptions of mosquitoes come from places temporarily filled by heavy rains."

It appears then, that New Jersey is naturally provided with a sufficient fish fauna to take care of nearly all the mosquitoes that attempt to breed in natural waters. That the only lack is a top minnow capable of taking care of *Anopheles* in bodies of water filled with vegetation. That the top minnow, *Gambusia affinis,* is a fish such as is needed and that there is at least a fair chance of its successful introduction into the State.

CHAPTER II.

REMEDIAL MEASURES IN GENERAL.

Broadly speaking, there are two methods of dealing with the mosquito subject. Destructive, reaching the insects in some stage of their life cycle; and preventive, making it impossible for the insects to breed. The object of this investigation was to ascertain so far as might be in what manner permanent improvement in conditions favoring mosquito breeding might be achieved. It was realized that breeding areas were so extensive and so widely distributed that any suggestion of a method looking to the destruction of larvæ, that would have to be repeated several times annually, would stand no possible chance of acceptance. The popular idea of mosquito destruction is a covering of oil or some other material on pools and ponds where mosquitoes breed and, based upon this view, the current disbelief in the possibility of satisfactory results is justified.

The results of the studies as given in the general reviews forming Part I, and in the specific descriptions in Part III, demonstrate beyond all reasonable doubt that, while the mosquito fauna of the State is a fairly rich one, there are really only five species of *Culex* and the species of *Anopheles* that need attention from the practical standpoint. Of the five species of *Culex* three breed on the salt marshes and may be dealt with as one; one breeds in fresh water swamps and in the more permanent pools generally, and one breeds anywhere; preferably in temporary pools or stagnant bodies large or small, clean or foul. The salt marsh species are all migrants and cannot be controlled by any sort of work done in localities inland, no matter how badly they may be infested. *Culex sylvestris,* the swamp species, must be dealt with at some little distance from the local point to be cleared, for it flies a mile or two at least and perhaps more. *Culex pipiens* is practically a local proposition and, out of range of the salt marsh species, is the chief pest. The species of *Anopheles* occur with all the others and whatever local measures are adopted for them will be of influence on the malaria carriers as well.

It has been emphasized wherever possible, that water is needed to produce mosquito broods and that the great bulk of the insects came from small temporary bodies while large ponds or

streams were safe. The obvious conclusion is that if we dispose of the surface water the mosquito problem is solved and, in general, that is the gist of the recommendation made. But as conditions differ for the various species it will be better to treat them separately.

THE SALT MARSH SPECIES.

The home of these species is everywhere along the coast within the influence of the marsh vegetation; but especially on those soft marshes of irregular surface just above the level of ordinary high tides. In the depressions in these marshes water from extra tides and from heavy rains, settles and remains long enough to mature a brood. A marsh of this character is like a huge sponge and becomes dry only under the influence of a long continued drought. Take out a sod in such a marsh and the hole fills with water; open a ditch and from thirty to sixty feet on each side all the water held in the marsh will flow into it. Such ditches to be of the greatest effect and most lasting, should be at least two feet deep, while the width need not be greater than enough to hold the ditch. In a marsh well covered with sod, with a mud bottom several feet deep, a six-inch ditch is really better than a broader one, because, by the shading of the banks, mosquitoes are repelled and do not oviposit in it. Nor does vegetation start readily from that low level and the ditches are therefore likely to remain cleaner than shallower ditches would be. The deeper the ditch the more complete the drainage and the further to each side the influence will extend. Practically from two to two and one-half feet deep and six inches wide at intervals of from sixty to one hundred feet forms an excellent working formula for any ordinary marsh that is evenly infested. It has been indicated however that there is a comparatively low percentage of marsh area that will require such treatment.

Taking the infested marsh-land as a whole it is probable that about eighty per cent. of it is amenable to this narrow ditching method, and these ditches, if undisturbed, will last for years without attention. A very small percentage of the entire area will be found too soft to maintain a narrow ditch and for these wider channels must be dug, which will, in a year or two, so improve the general character of the marsh that narrower ditches can be used where necessary. A considerable area on the Barnegat Bay shore has only a shallow sod covering over the sand and here ditching is practically unavailable as a general method. Shallow ditches will help out individual cases and where there is an

eighteen-inch sod they will last well; but the tendency is to fill and choke and they will need constant looking after.

Taking the marsh area as a whole there is a very good natural drainage in most sections by means of "Thoroughfares" and "Slews," to which artificial, ditch drainage can be led. It will prove surprising in many localities to find how little work is actually needed to remedy serious conditions.

First and most important then of the methods of dealing with the marsh mosquitoes is such drainage as will prevent the formation and maintenance of shallow pools by extra tides or heavy rains. The drainage need not be such as will make the land suitable for agricultural or other practical purposes, except possibly for salt hay, and it need not be so extensive as to completely drain the land with the retreat of the tide or the cessation of the rain; but it must be sufficient to remove all surface water within forty-eight hours.

Over a large marsh area the ditches will be all that is necessary, because the depressions are shallow, rarely holding over four inches of water when completely filled. Where the holes are deeper, as they sometimes are, they must be filled with the sods taken from the ditches unless they are so large as to maintain fish continuously. At a depth of twelve inches a hole or depression itself acts as a drain from the surrounding territory, and if at all close to the ordinary high tide level, the last few inches will disappear very slowly, giving ample time for the brood to develop. I have seen sometimes a pool of this kind reduced to an area of three or four square feet and so crowded with larvæ and pupæ that it seemed as if there could not possibly remain space for even one more. Sods should always be removed from the immediate edge of the ditch to prevent their falling in or being floated in by a high tide and, so far as they go, they may be used to fill up even the shallower holes and depressions. Occasionally it happens that there is a depressed area in an otherwise safe meadow at a considerable distance from any natural watercourse, and in such a case converting it into a permanent salt pond with steep banks is the best method of dealing with it. Such a pond should be at least two feet six inches deep and should be stocked with killies from the nearest natural watercourse. Other marine life will come in with the spring tides and a dangerous breeding area will be made safe. No vegetation will start in the bottom of such a pool, but a shallower one would soon become obstructed and dangerous. The material removed from the pond may be used in filling at points nearby, or in lessening the extent of the area to be excavated. Very frequently slight depressions or small holes can be wiped out by

Figure 35.

Hand ditching on the salt marsh. A gang of Italians. (Original.)

cutting the grass and other vegetation round about and piling it over the little breeding places. This, by the bye, is an excellent way of dealing with breeding places in roads where a soft spot is rutted by wagons driving through it until it holds water enough to mature a brood of mosquitoes. It is also a good plan to burn over a marsh that is not used for hay, or during the winter in any case. For some reason the mosquitoes seem to shun these burnt areas, and Mr. Viereck, who kept such a place under observation for some time, reported no developing larvæ and few adults during the season. It tends also to the leveling and more rapid drying out of the marsh and every method or practice that has this effect is to be commended. The intent is to level the surface so far as possible and to provide an outlet for the water that falls upon or covers it. Once that is accomplished the area is mosquito safe and will remain so indefinitely if the ditches are looked after each year and the marsh is kept under occasional observation to note the possible development of breeding areas through storms, the carelessness of those who may get up on it for hay or other purposes, and through any other cause whatever. During the winter storms, for instance, or when very high tides have covered the meadows, some of the drains may become obstructed by driftage and that would, of course, interfere with their proper working. A little work in early spring would be all that is necessary with a survey in midsummer or earlier to fill with vegetation any overlooked or newly developed surface pool.

The ditching may be done either by hand or by a machine like the "True ditcher." Where the area to be cleared is large and long ditches are needed, the machine work is cheapest; but where the area is small or the ditches are numerous and short, hand work is most economical. Machine ditching should cost little over one cent per running foot, but if sods are to be removed and holes to be filled, that will add to the cost in proportion to the amount of such work to be done. It ought not to exceed one and one-half cents per running foot in any case. Hand ditching costs a little more, but unless the territory is unusually difficult, one and three-quarter cents should be considered an outside figure for even the worst territory.

For machine ditching a very satisfactory machine is that used on the Newark meadows, known as the "True ditcher," by means of which from 3,000 to 4,000 feet of ditching two feet deep and from six to twelve inches wide, may be cut in a single day.

For hand ditching long narrow steel spades are used, square edged to cut the sides, curved and a little grooved to level the

bottom. It is important that the bottom of the ditch be as level as possible to prevent any obstruction to the flow of water, and at the outlet the ditch should be a little wider and deeper to give unobstructed exit to the drainage.

In those areas where the sand comes so close to the surface that no ditching can be done, and in those swampy depressions among the sand hills that have no outlet, filling is the only remedy. Along the Barnegat strip especially, a very large percentage of the mosquitoes are bred among the sand hills just back of the shore line, and the filling for these depressions is at hand, surrounding them. For filling in large areas, hydraulic dredges are necessary. Examples of their work can be seen at Atlantic City, Cape May and the Kearney Meadows, and a large extent of territory can be covered by such a dredge in a single day. This sort of work is necessarily expensive* and available only on a large territory; but in a single season the entire strip from Point Pleasant to the Barnegat Inlet can be made completely mosquito proof, since only a shallow covering of sand would be required to raise the higher and dangerous marsh area permanently above the high tide level. As the bay bottom is a fine sand, filling material of the best quality is at hand in unlimited quantity.

Where inland filling among the sand hills is to be done, it is a good plan to put on first a layer of coarse drift or sedge hay, upon and among which the sand can be shoveled. This will hold the material and prevent blowing, which is responsible for the formation of some of these basins.

At several points along the shore, stretches have been laid out into town plots, and streets and roads have been built. These streets are often a little higher than the surrounding territory, and no provision is made for the drainage of low-lying lots. Indeed, as a rule, the natural drainage is cut off and nothing is substituted, the result being the formation of the liveliest kind of breeding places. Such lots usually grow a rank vegetation, and if this is systematically cut and piled on the lowest spots, a little sand being added to give weight, a condition will be formed which will at least prevent mosquito breeding. In other words, in all the shore cities, towns, villages and resorts especial attention should be paid to the surface water within the limits of the settled or plotted area, for it is my experience that a very large percentage of the mosquitoes in such places breed within their own limits and can be controlled by local work. Too much

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*I am informed that 15c. per cubic yard of filling is an average price on an area sufficiently large to make the dredges pay at all.

importance cannot be given to the use of vegetation as a filler for mosquito breeding pools in the sand hills and low lot areas. Two or three men with scythe, fork and shovel can put out of service a large number of breeding pools in a single day, and this method, though a makeshift in some cases, has the advantage that it is good for a season at least and does not cost very much to carry out.

The systematic drainage or filling of the marshes along the coast would affect almost the entire State south of the Red Shale, and a considerable area along the valleys of the Raritan, Hackensack and Passaic Rivers.

No place is given here to measures of a palliative character, such as coating with oil, because that is a most temporary benefit at best. Nevertheless in local breeding places in advance of permanent work, kerosene and fuel oil act as well as they do in fresh water.

THE HOUSE MOSQUITO.

In dealing with this insect we meet with what may be known as obligatory breeding places of a permanent character, due to the exigencies of modern civilization. In accounts of this species stress has been placed upon the fact that it breeds in foul water, including sewer catch-basins, cesspools and gutters, as well as in the clean water of rain barrels and cisterns. Sewer catch-basins and drains in park roads must of necessity remain open to the air, and in these catch basins there is always, also of necessity, enough water to maintain a mosquito brood. In such a case nothing remains except to kill off the broods systematically throughout the season, using either fuel oil, kerosene, Phinotas oil, soluble crude petroleum or chloronaptholeum. Fuel oil or kerosene are cheap, simple and effective, but objectionable because of their odor. As the materials act as a surface covering only, the least addition to the water in the catch basin will float the oil into the sewer itself and the basin will be ready for another brood of larvæ. Nevertheless where this method is applied systematically, many thousands of larvæ are destroyed at a very slight expense, and the decrease in the number of adults is followed by a corresponding decrease in the number of larvæ in later broods. Chloronaptholeum is an excellent larvicide and a good disinfectant, but its cost is prohibitive. It has the advantage that it poisons the entire water and remains effective for some time against young larvæ even when considerably diluted by additions. Phinotas oil and soluble crude oil cost about alike and are equally effective, but the Phinotas oil acts more promptly

and diffuses more quickly through the water. Both materials mix with the water and may be very greatly diluted without losing their effectiveness; but the Phinotas oil has disinfecting properties and stands a very much greater dilution. It is the most effective larvicide known to me, and for sewer catch basins it has no equal. It should be applied with a gardener's syringe through a fine rose nozzle, and two ounces will be abundant for the ordinary city catch-basin. The syringe distributes the material evenly over the surface, economizes the oil and should be used for all the substances suggested. If a syringe is not available, a sprinkling pot with a fine rose will answer. Work on catch basins need not begin, ordinarily, until the last week in May and need not be done until four or five days after a heavy rain that has flooded the basins. Under ordinary conditions ten days may be allowed to elapse before another treatment is made, and if then or thenabout a heavy shower flushes the basins, they are safe for at least five days more. In ordinary seasons, with a normal amount of rain, no more than half a dozen and perhaps even fewer treatments will be necessary. It must be a matter of discretion with the officer in charge to select those periods when, with a brood of larvæ approaching maturity, he can kill them off and gain safety for a week to come.

Cesspools, where they occur, should be completely covered, or if ventilated, should have a wire screen over the mouth of the opening. If it be for any reason impossible to cover completely, a liberal application of Phinotas oil will ensure safety for a long time. Fuel oil will evaporate slowly and will maintain a safe film for two or three weeks.

Manure pits should be dealt with as are cesspools, save that no Phinotas oil or other germicide should be used. The fuel oil is best here, provided a tight cover cannot be maintained.

The drainage system in parks where there is an overflow from lakes or ponds or where the surface water is carried off through pipes should be especially well looked after, because breeding is even more free there than in the sewer basins of a city. In Central Park, New York City, Dr. Berkeley, Mr. Seal and myself found under every grating that we lifted larvæ of this species in the settling pool. Mr. Brehme found the same condition of affairs in Branch Brook Park, at Newark.

Gutters kept in proper repair and properly graded can never become dangerous; but gutters used as receptacles for house waste, broken or defective so that water lodges in them, form excellent breeding places. Where the gutters are unpaved or mere grooves or shallow ditches partly choked by vegetation, mosquitoes find a congenial home for their larvæ. For such

Figure 36.

A hand-dug ditch on the salt marsh. (Original.)

gutters chloride of lime liberally applied or chloronaptholeum diluted and used as a disinfectant may serve as a cure; temporary of course and a makeshift for proper drainage.

Cisterns, where they serve as a source of water supply, should be completely covered if possible, with overflow and inlet screened with wire netting. Where that is not possible, a few "killies," "roach," "shiners" or other little fish of that character may be introduced and will take care of all the larvæ that may appear. Even sunfish or goldfish will answer where "minnows" are unavailable, and they will not foul the water as much as the mosquito population would do.

Rain barrels, where they are necessary, should be treated like the cisterns and they will maintain killies very well. If fish are not available, a coating of kerosene will not render the water unfit for use if it can be drawn from a spigot at the lower portion.

Pools in vacant lots are prolific sources of supply and these should be filled in all cases or drained into the sewer or other general drainage system. In a city or town where the ashes and garbage are collected by the municipality the ashes and dry waste can be used for such filling as is necessary. Whatever the method that is most available, which will vary under different circumstances, the object must be to get rid of the accumulations of surface water. Attention should be again called to the availability of the vegetable growth that is usually rank in moist spots to serve as a filler in shallow areas. It does not make a permanent or solid filling but it fills the water so that mosquito larvæ cannot readily move about in it, while the adults cannot reach the surface to oviposit.

There remain to be considered those accidental receptacles like tin cans, old buckets, tubs, etc., that may be anywhere in back yards, in vacant lots, in dumps, or even in cellars. For such breeding places the individual maintaining them must be made to feel responsibility in some way. Generally it is only necessary to point out to the individual concerned that he is the chief sufferer, to induce him to take the necessary steps. A case in point is a row of cottages in a sea shore resort where mosquitoes in some numbers occurred on all porches; but on one in particular life was almost unbearable as darkness set in. Investigation showed an unused rain barrel half filled with water swarming with larvæ of all sizes, and pupæ from which adults were constantly emerging. Half a cup of kerosene placed the porch on an equality with its neighbors.

It seems, at first sight, as if a great deal was required; but it must be remembered that most of the methods recommended

mean permanent improvements and need be done once only. As to those methods which are directed to the destruction of the larvæ rather than the abatement of the places where they breed, if they are systematically pursued for a year or two they will effect such a reduction in the number of the insects that the number of applications may be reduced each year until only specific cases need be dealt with.

It has been suggested that it might be well to provide breeding places for hibernating specimens on the theory that the first brood might be in this way destroyed, and that is not at all bad. My experience for several years has been that I find wrigglers of the house mosquito in my pails in May, before I find them in pools elsewhere. It is almost certain that these larvæ are the progeny of the specimens that have hibernated in my own cellar and that they have made use of the nearest available place to oviposit. It means only dumping these pails when they contain a brood of wrigglers and refilling them afterward to attract what other specimens there may be about. In that way the breeding about a place can be localized and controlled, especially in a dry time, because it will afford a place for oviposition and leave few or no examples for rain pools when they do make their appearance. But this is a method for individuals and must be looked after closely by the persons attempting it, lest by inattention or carelessness an opposite result be obtained. An old tub or a half barrel makes the best trap and should have about six inches of water. A little garden soil in the bottom and a handful of old leaves or dry grass will start organic life on a scale to make the water attractive and the rest is easy.

It is against this particular species that, in our State, the oil treatment has been especially directed, and the method has been highly successful despite apparent contrary reports. The difficulty has been that while the locals were kept down, the migratory forms supplied the pests that were noted and the method was charged with failure. In one sense of course the campaigns were failures, in that exemption from the mosquito pest was not obtained; but on the other hand the means were effective as against all the specimens that could be reached by them. The only trouble was that the work should have been done and the money spent miles away.

The best evidence of this statement is found in the collections of mosquitoes sent in at short intervals from several of these places; for in these the locals were either absent or in the great minority; so scarce indeed that, with the salt marsh species eliminated, the localities would have been practically mosquito free.

The true mosquito campaign is that which aims at permanent

relief and against the salt marsh species any other would be idle; but when local conditions offer a great variety of breeding places that cannot all be dealt with promptly as well as permanently, the best and most prompt effects can be obtained by dealing with the breeding places with larvicides of some sort. Kerosene of low grade and fuel oil seem to produce the best film, and one ounce will cover about fifteen square feet of water area if put on carefully or in a fine spray. As a matter of fact twice that amount or even more is usually applied by means of a watering pot or even a dipper. Applied on the surface of a breeding pool these materials produce a coating that is fatal to both larvæ and pupæ when they attempt to pierce it to secure a supply of air. So long as the film remains it will be fatal also to the adult mosquito that attempts to oviposit on it. But the larger the pool and the more exposed it is to air currents, the sooner its effect disappears. In sheltered places the oil may remain visible for several days and be effective for an even longer time. In unfavorable or exposed places a wind may blow the oil film to one side after a short period, leaving a portion safe for oviposition, though the brood present when the application is made will be killed. The soluble crude oil, Phinotas oil and chloronaptholeum remain effective much longer, rendering the water permanently unfit for mosquito breeding until additional rains dilute them beyond the points at which they kill. In New Brunswick the chloronaptholeum has been used by the local Board of Health with good effect, and it is less objectionable than the others, though more expensive and, on the whole, less active.

In large hotels, especially at the seashore, there are often indoor breeding places in water tanks, fire buckets, the water cushions under elevators, or in some cases under the buildings themselves. I have known of cases where hotels were infested the year through, the species breeding continuously, and I have record of a factory in which the storage tank for reserve water supply was found absolutely swarming with wrigglers. The water in the space below the lower flooring of some of the shore hotels I find is a common occurrence, and accounts for much of the indoor trouble late in the season, when outdoor mosquito life becomes less offensive. In all cases of these sorts practical necessities must determine the method to be used. Enough has been said to serve as a guide to any intelligent man before whom such a condition may present itself indoors.

It should be kept in mind always that any body of water, no matter how small or however foul, is likely to serve as a breeding place; but it should also be kept in mind that there are many bodies of water where the insects do not breed, and it behooves

any one who attempts to conduct a mosquito campaign to know that the real danger spots are aimed at. Indiscriminate oiling of ponds and streams where no mosquitoes are known to breed and where other measures are available in case they do, is bound to raise opposition, increase expense and to fail in obtaining proper results.

THE WOODLAND SWAMP MOSQUITO AND THE MALARIA CARRIERS.

These may be dealt with as one, because they usually occur together. The species of *Anopheles*, however, also occur with the house mosquito, and in almost any place except positively foul water they may and do also occur. All the methods suggested under the previous heading will aid in keeping down the malaria carriers.

Culex sylvestris favors swamp areas large or small, and often occurs in low, soft springy land, in holes where water stands. Places of this character are often drainable by a ditch into a natural water course; indeed the swamp area usually has an outlet through which a slow drainage occurs, and it may only be necessary to open a way for the more rapid carrying off the waters. *Culex pipiens* may also breed in such areas, so they deserve careful attention in any case.

Occasionally it happens that such a depressed area is of considerable extent or in a pocket not easy to drain without considerable expense. In such a case a small pond may be formed, sometimes by a dam, if live water enough comes in to maintain a little flow through it, sometimes by digging out a pool and using the excavated material to fill at the edges and make a proper bank. In the former case the depth should be great enough to make the water reach a firm edge at all points; in the latter the pool should be not less than two feet deep with provision in each case for an overflow; if possible also for a complete drawing of the water, should that at any time be deemed desirable. A pond or pool of that kind, stocked with almost any small fish will be a safe and pleasant substitute for a dangerous and ugly breeding area. An instance of this sort of work is near Metuchen, on land of Mr. Thomas A. Edison. It is important to have the edges clean and without overgrown shallows, that fish may get in everywhere and no shelter be available for *Anopheles*. It is equally desirable to have the pond elsewhere sufficiently free from vegetation to allow of the unrestricted movement of fish everywhere.

The essentials pointed out for the artificial ponds should be carried over to natural ponds and swamp areas that cannot be

Figure 37.

The True ditching machine at work on the Newark meadows. (Original.)

drained or that are held to be desirable for any reason. Drainage for swamp areas is always best, wherever possible, but dense woodland swamps or huckleberry swamps or such as are very densely overgrown with tall vegetation require no treatment. The dangerous areas are those that are open, partly filled with grasses, reeds, lilies, arrow heads and other plants of that character and with overgrown shallow or grassy edges. Such an area though it may be naturally stocked, is dangerous, because the grasses and other plants are so dense that the fishes cannot move among them. There are many little spaces, therefore, where the wrigglers are undisturbed, while *Anopheles,* keeping on the surface over partly submerged leaves, is beyond the reach of our native fishes. Such a swamp area if not readily drainable should be opened up by taking out the obstructing vegetation or cutting it below the surface, that the wind may have unobstructed swing and surface feeders among the fish may be able to move about freely. The shallow edges should be deepened and the material removed used to limit the swamp areas or fill shallow indentations or detached depressions. If only a small amount is available the vegetation at the edges may be burnt with a gasoline blast torch, of which there are several types on the market, one of them especially adapted for this sort of work. With such a torch even green vegetation can be scorched and destroyed to the water surface, forming a clearing sufficient to expose the larvæ to their natural enemies. Oil or other larvicide applications are unsatisfactory in such areas. The preparations that are supposed to mix with the water are cut out because of the amount of water to be affected and the surface oils are difficult to get among the grasses and overgrown edges so as to really cover the surface. Conditions demanding treatment will vary; but the underlying principles are, drainage where possible; open water stocked with fish where drainage is impossible. The conditions favoring the development of mosquitoes have been described at length in general and in detail for each species. The task is to remove these favoring conditions. Any practical engineer should be able to deal with local problems once the source of danger is fixed.

Running streams are rarely sources of trouble; but where they are sluggish or form shallow overgrown pools, or are obstructed in any way, some *Anopheles* may and often do develop. In such cases the bed of the stream should be cleaned or the channel should be deepened, using the material removed to fill the shallow edges and narrow the bed. Under the conditions usually found in streams, breeding is so very restricted that it

may be practically ignored except within actual city or town limits.

The *Anopheles* or malaria carriers have no breeding places that are peculiar to themselves alone. Hence a campaign against them is bound to hit practically all the local breeders, while a campaign against all local breeders is equally certain to reach *Anopheles*. But, while the species do occur everywhere they are much more likely to occur with *sylvestris* and especially in swamp areas and sluggish streams. *Sylvestris*, as has been shown, flies for some distance, hence a community desiring exemption must seek out its chief breeding areas for at least a mile from the point to be cleared.

Oil kills *Anopheles* as readily as it does *Culex*, but it is not always so easy to get it where it is needed. Oiling a stream of any size creates an offense out of all proportion to the results to be obtained, and the results are bound to be imperfect because the insects retreat to sheltered situations where the oil does not readily penetrate, and where the film is broken against the grass and other debris. Even a slow current will carry off the oil film in a few hours, if not, indeed, in a comparatively few minutes. The same difficulty in doing effective work with oil applies to swamp areas more or less choked with vegetation. Yet it would be possible, of course, to do real thorough work if time, material and labor were no objects. The chief objection to its use is really its temporary character. It must be done several times during the season and at the beginning of the season thereafter absolutely no progress has been made and the work ahead is practically the same as was done the year before. The expense is a continuous one and equally great each year, while with permanent improvements such as result in the eradication of a breeding place though the initial expense be greater, the result is continued exemption without further outlay except for maintaining conditions.

CHAPTER III.

DESTRUCTIVE METHODS.

LARVICIDES.

The main effort in this investigation was to determine what methods of obtaining permanent relief are available; but it is realized that some places are chronic breeders which, like sewer basins, cannot be abolished, and others must sometimes be dealt with in advance of permanent work to avoid the emergence of a swarm that would otherwise mature and infest the neighborhood. In fact, during the beginning of the work in any locality, some means of obtaining immediate results are necessary.

During the summer of 1902 quite an elaborate series of experiments were carried on to determine the relative value of a great variety of disinfectants and mosquitocides. Some of these were ordinary commercial products, made and offered without reference to their effect upon mosquito larvæ; others were special preparations sold under a trade name, composition not given or only generally stated. The detailed notes of these experiments were destroyed in the laboratory fire early in 1903, and only the general statements or conclusions can now be given.

As to the special preparations, except such as are hereafter mentioned, they were all more or less effective, but all of them so expensive in proportion to the results obtained that they may be left out of consideration entirely.

The soluble *Carbolic acid* and *Cresol* preparations were all effective at some strength; but most of them were too expensive for general work and had the disadvantage of permitting pupæ to mature even where the larvæ were killed.

Permanganate of Potash was very carefully tried, because much had been claimed for it; but it was found to have practically no destructive effect whatever. A solution so concentrated that in a two-quart jar the larvæ and pupæ were not visible unless close to the glass side, did not kill mature larvæ and permitted the development of all pupæ. Smaller larvæ died in a day or two, and that was the effect of all strong mixtures. When the permanganate solution was reduced so as to permit seeing through the water in the jars, it produced practically no effect at all. The details are lacking, but the conclusion is positively remembered.

Chloronaptholeum, a product manufactured by the West Disinfecting Company, of New York, is used as a general disinfectant by the New Brunswick Board of Health, of which the writer has been a member for a number of years. A series of experiments proved that this material was effective as against mosquito larvæ, even when greatly diluted, and beginning toward the end of May, 1903, all dirty gutters, sewer catch-basins, drainage ditches and lot pools in the Sixth Ward, in which I reside, were treated whenever I found a brood developing. The material was diluted with fifty parts of water in the disinfecting cart and applied with a garden sprinkler until the water in the treated places was milky. As general disinfection was also aimed at, the material was used to excess in gutters and drainage ditches. The species that breed in these treated places are *Culex pipiens, restuans, sylvestris, jamaicensis* and *Anopheles maculipennis*. The result was perfect. Until the arrival of the salt marsh species, about July 1st, scarcely a mosquito was noticed on my porch, and after their advent frequent collections showed local forms at rare intervals and in small numbers only. Examinations of the treated pools were frequently made, and in every instance it was known that larvæ were present and that the application had killed them. On one occasion the application was delayed until pupæ were generally present, and in that case some of the adults emerged. This material shares the weakness of other Cresol preparations, in that it does not kill pupæ at a strength which is fatal to the mature larvæ.

For a general disinfectant, however, this material has a high value as a larvicide, and it is available for general use in places where oils would be objectionable. It does not act well in salt water, however, and is of no use on the marshes where the water is brackish or with more than a mere trace of salt. The cost is about $1 per gallon, or too high where the mosquito alone is aimed at.

Phinotas oil is a preparation made by the Phinotas Chemical Company, of New York, and it is the most effective larvicide known to me. It acts by poisoning the water and also forming a film over it. When applied from a sprinkling pot or a sprayer in globules, these sink to the bottom, begin to dissolve, turn the water milky, and in time seem to take bubble forms, which rise to the surface, burst and spread out in an oily film. This is effective even in the smallest quantities, and larvæ and pupæ begin to die within a few minutes after the application. Its action is so violent, indeed, that all other aquatic insects and even fish succumb at once. Its very effectiveness limits its use to sewer catch-basins, cesspools and temporary lot pools, for which noth-

Figure 38.

Machine ditch, showing how the whole sods, 30 x 6 x 10 inches each, are laid in series along the ditch. (Original.)

ing is better. Used wherever there are any fish, these will be killed with the wrigglers that may be at the edges, and after the material has disappeared the mosquito development will be greater than ever, because even the open areas will then be safe to them, for lack of fish to keep them down. Nevertheless, the Phinotas oil is a valuable auxiliary in a mosquito campaign, and its cost, about 40 cents per gallon, is not excessive in proportion to the effects obtained. In my notes I had determined the minimum amount that was certainly effective; but as these are lost, my recollection that it was 1 part in 100,000 parts of water must be accepted subject to revision after further tests.

It has the advantage of being fatal to pupæ at the same strength that it kills larvæ, but it is not soluble in salt or distinctly brackish water. It is therefore of no value along shore except in rain pools or where there is only a mere trace of salt in the water.

The simplest and cheapest larvicide is *common kerosene* of low grade, or, better, the material known as fuel oil. It costs from 10 to 13 cents a gallon, or even less, and an ounce of it applied as a spray will cover about fifteen square feet of water area with a film sufficient to kill all mosquito larvæ or pupæ that rise to the surface to breathe. Young and mature larvæ are equally affected, and pupæ resist very little more. Fish and insects that do not come to the surface to breathe are not affected, and those diving beetles that must get their supply of oxygen from the air will fly from the pools as soon as they discover the presence of the oil. So long as the film remains, any adult mosquito that attempts to oviposit on the surface will be caught and killed. It acts almost equally well on salt water, and the only drawback is that the film is easily broken and may be driven by even a slight wind to one shore, where it is absorbed by the soil or in the vegetation, leaving a free field for a new infestation. In sheltered pools or in barrels the film lasts a long time, and even after the oily gloss has disappeared there is a remnant that is effective. It may be used in rain barrels or cisterns where the water is drawn from the bottom; but unless the film is very thin, a slight taste of oil will be detected after a few days. If the water is used for washing or other purposes than personal consumption this will not matter.

The oil has no disinfecting qualities and is offensive in gutters and drainage ditches, hence I prefer to use the chloronaptholeum there. That there is a difficulty in reaching *Anopheles* and other larvæ that seek shelter among dense vegetation is no fault of the oil. It is a matter of application, referred to only to indicate that the subject is elsewhere discussed.

Crude petroleum, light and heavy, has been used as a substitute for kerosene, but neither is as satisfactory. The heavy oils form globules that hang together and tend to unite in a mass rather than to spread out in a film. The lighter oil spreads better at first, but as the gasoline and other volatile parts evaporate, the vaseline and other heavy products tend to draw together.

A *soluble crude oil* has been prepared by a Baltimore firm and sent me for trial. Used in the laboratory it mixed readily with water and killed promptly all the larvæ and pupæ in the trial bottles. While it clouded the water a little, it did not turn it milky and the action was a little slower than that of the Phinotas oil.

August 26th, I sent out two of the boys with instructions to spray the lot pools in New Brunswick from which our experimental material was usually derived. An atomizer was used and a very small amount of the material was needed: the instructions were to simply cover the surface and to see what would happen. The report was as follows: "The spray looked about like water and it gave the pools a clouded appearance. The larvæ and pupæ became active and uneasy as soon as the surface was covered. Half an hour after the spraying a great many of the pupæ were dead; but most of the larvæ were still active, although they did not act naturally. The petroleum also affected the other insects: numerous dead beetles and water boatmen were noticed, and quite a few climbed out at the sides and on the stones to escape.

"August 27th, examined the pools which were sprayed yesterday and found that the water has the same cloudy, dirty appearance and as if there was a scum of grease on the surface. The larvæ and pupæ were all dead, except one pupa in one of the smaller pools and one larva in the largest pool. The pupa was nearly dead, but the larva was quite lively.

"Quite a number of dead adult *Chironomids* as well as *Culex pipiens* and one *C. jamaicensis* were noted on the surface."

September 2d I sent one of the boys out for further observation, and he reported half the pools entirely dry, others with only an inch or less of water and one with six inches of water, with numerous egg boats and a large number of recently hatched larvæ.

This observation is important because in five days after an application which killed off nearly all insect and all mosquito life, the area was again infested, though there had been practically no addition by rains and there had been, indeed, an actual shrinkage in the size of the pool.

It puts the material, which costs about thirty cents a gallon, on a par with the fuel oil, which costs only one-third as much, and has the advantage of not killing the beetles and other insects that live beneath the surface.

Sulphate of Copper in simple solution and combined with lime to form the "Bordeaux mixture," has been found by the United States Department of Agriculture (Bull 64, Bureau of Plant Industry) to be wonderfully effective as against certain forms of algæ and other microscopic animal and vegetable life. Its effectiveness against mosquito larvæ is only incidentally referred to; but the popular accounts translated that into a more positive statement than was, perhaps, intended, and I had Mr. Dickerson make a series of experiments to test the effectiveness of the material as against both fresh and salt water species.

Mr. Dickerson's experiments and the conclusions he draws from them may be given in some detail to answer questions that have been frequently asked and will be certain to come up again when mosquito campaigns become more general.

As a preliminary experiment of my own I placed a number of pupæ of *Culex pipiens* in a bottle of the concentrated copper solution at 4:30 P. M., and before evening adults began to emerge. Eighteen hours later another adult emerged and one very lively pupa was present after twenty-four hours. The remainder of the pupæ, less than 50 per cent. of the whole, were dead.

At the same time, a few larvæ of *C. restuans* of various sizes were placed in another bottle of the concentrate. Half an hour later the smallest larvæ were dead and early next morning all were dead. It is interesting to know that even the concentrated solution failed to prevent the development of the adult from the fully matured pupa, though no larvæ reached the pupal stage in the solution.

Mr. Dickerson's report is as follows:

Experiments with Copper Sulphate Solution on Culex Larvæ.

Copper sulphate was used in varying amounts on several lots of *Culex* larvæ and pupæ to test its killing properties. The solution used in these experiments was prepared by adding half a pound or 3,500 grains of copper sulphate to 1,275 cc of water, thus giving 2.74509 grains of copper sulphate for each cc of the solution used. In each case the amount of water in the experiment jars was weighed, and thus the proportions by weight of water and copper sulphate were obtained.

Experiment 1: with very small larvæ of *Culex pipiens,* breeding in pails at New Brunswick. They were placed, together

with a small amount of the water in which they were breeding and some of the bottom or food material, in three jars of city water, to which copper sulphate enough was added to give the following proportions:

Jar 1—1 part of copper sulphate in 1872 of water.
Jar 2—1 " " " " " 976 " "
Jar 3—1 " " " " " 624 " "

This experiment began at 2 P. M., and during the afternon the larvæ remained in apparent good health; but at 8 A. M. next morning all were dead. The larvæ in a check jar were doing nicely when this experiment ended.

Experiment 2: with full grown larvæ and pupæ of *Culex cantator* collected in brackish water on the Newark meadows. They were placed together, with some of the bottom or food material and a small amount of breeding water, in three jars of city water. Three days later, adults having begun to emerge, copper sulphate enough was added to give the following proportions:

Jar 1—1 part of copper sulphate in 3587 of water.
Jar 2—1 " " " " " 1873 " "
Jar 3—1 " " " " " 1292 " "

Eighteen hours after the addition of the copper sulphate the larvæ and pupæ were in apparently healthy condition. Forty-two hours thereafter the conditions were unchanged. After sixty-four hours the pupæ were active and hatching, but the larvæ were dead, except for two in Jar 1 and one in Jar 2. Ninety-six hours after it began conditions had not changed and the experiment was closed.

Experiment 3: with full grown larvæ and pupæ, mostly *C. pipiens,* collected at Vailsburg. Together with a small amount of food material and breeding water, they were placed in eight jars of city water, to which copper sulphate was added to give the following proportions:

Jar 1—1 part of copper sulphate in 4382 of water.
Jar 2—1 " " " " " 2072 " "
Jar 3—1 " " " " " 996 " "
Jar 4—1 " " " " " 737 " "
Jar 5—1 " " " " " 577 " "
Jar 6—1 " " " " " 456 " "
Jar 7—1 " " " " " 297 " "
Jar 8—1 " " " " " 219 " "

Eight hours after the addition of the copper sulphate the larvæ and pupæ were in an apparently healthy condition and the

pupæ were hatching. After twenty-four hours the conditions were unchanged; but some of the larvæ had pupated and some adults had emerged. After seventy-two hours there were some dead larvæ in all the jars; but the fewest in Jars 1-3; many more larvæ had changed to pupæ and more adults had emerged. After ninety-six hours more larvæ had pupated and adults had emerged; the majority of the remaining larvæ were dead; but there were two or three in each of Jars 1-6 and one in each one of Jars 7 and 8 still active. The experiment was ended at this point with several larvæ still active in a check jar, in which development did not take place as rapidly as in the experiment jars. The water in all the experiment jars was more or less thoroughly cleared, while that in the check jar retained the characteristic cloudy appearance of the pool breeding liquid.

Experiment 4: with full grown larvæ and pupæ of *Culex cantator* breeding in brackish water on the Newark meadows. They were placed with the water in which they were found in three jars and enough copper sulphate was added to give the following proportions:

Jar 1—1 part of copper sulphate in 900 of water.
Jar 2—1 " " " " " 442 " "
Jar 3—1 " " " " " 308 " "

Half an hour after adding the copper sulphate the water began to clear; twenty-four hours thereafter the water was clear, with the larvæ and pupæ in apparently healthy condition. After forty-eight hours almost everything was dead, only a few larvæ—three in Jar 1, and two in Jars 2 and 3—and pupæ were still alive when the experiment ended. The larvæ and pupæ in a check jar, which retained the characteristic cloudy appearance, were in good condition when the experiment closed.

Experiment 5: with larvæ and pupæ of mostly *Culex cantator* and a few of *Culex sollicitans* breeding in brackish water on the Newark meadows. These were placed in four jars in the natural breeding water and enough copper sulphate was added to give the following proportions:

Jar 1—1 part of copper sulphate in 4466 of water.
Jar 2—1 " " " " " 2233 " "
Jar 3—1 " " " " " 1488 " "
Jar 4—1 " " " " " 1116 " "

Twenty-four hours after adding the copper sulphate many adults had emerged and the smaller larvæ were dead in all the jars. A few of the larger larvæ were dead in Jar 3 and all the larvæ were dead or dying in Jar 4. After forty-eight hours

many more adults had emerged in all the jars, only a few larvæ were active in Jars 1-3, while all the larvæ were dead in Jar 4. After seventy-two hours more adults had emerged, all the larvæ had either pupated or were dead and the experiment was closed. A number of larvæ were in apparently good condition in a check jar when the experiment ended. The water in the experiment jars cleared soon after the copper sulphate was added, while that in the check jar retained its cloudiness.

Experiment 6: with larvæ and pupæ of *Culex pipiens* breeding in pails at New Brunswick. They were placed, together with a small quantity of the breeding water and a little of the bottom food material in four jars of city water to which the copper sulphate was added as follows:

Jar 1—1	part	of	copper	sulphate	in	53552	of	water.
Jar 2—1	"	"	"	"	"	26776	"	"
Jar 3—1	"	"	"	"	"	13388	"	"
Jar 4—1	"	"	"	"	"	6694	"	"

Twenty-four hours after the copper sulphate was added a few adults had emerged in all the jars, and the larvæ were in apparently good condition except a very few in Jar 4. After seventy-two hours a few more adults had emerged in all the jars and in Jar 1 the conditions were unchanged. All the small larvæ and a few of the larger larvæ were dead in Jars 2-4 and the remaining larvæ in these jars did not seem so active. After ninety-six hours conditions were unchanged and the experiment was ended.

Experiment 7: with larvæ and pupæ of *Culex pipiens* breeding in a pool in a lot at New Brunswick. They were placed, together with a part of the breeding water, in eight jars of city water and copper sulphate was added to give the following proportions:

Jar 1—1	part	of	copper	sulphate	in	53552	of	water.
Jar 2—1	"	"	"	"	"	22776	"	"
Jar 3—1	"	"	"	"	"	13388	"	"
Jar 4—1	"	"	"	"	"	6694	"	"
Jar 5—1	"	"	"	"	"	3347	"	"
Jar 6—1	"	"	"	"	"	1673	"	"
Jar 7—1	"	"	"	"	"	1115	"	"
Jar 8—1	"	"	"	"	"	836	"	"

Sixteen hours after the addition of the copper sulphate a few adults had emerged in all the jars; there were a few dead larvæ in Jars 1-3, many were dead in Jar 4, most of them were dead in Jars 5 and 6, and all were dead in Jars 7 and 8. After forty-eight hours more adults had developed; there were a number of active larvæ in Jars 1 and 2, some in Jar 3, a few in Jar 4, a very few in Jar 5 and none in Jars 6 and 8. After seventy-two hours

conditions were unchanged except that the water in Jars 7 and 8 was much clearer than the others and the experiment was closed.

In all the experiments it is to be observed that the killing of the larvæ was gradual and irregular and hence the action of the copper sulphate upon them must be indirect rather than direct; by killing off the food organism and possibly by acting through the digestive system. A few larvæ of *Culex pipiens* succumbed to one part of copper sulphate in 53,500 of water in sixteen hours; others survived one part of copper sulphate in 3,300 of water for seventy-two hours, while one survived one part of copper sulphate in 219 of water for over ninety-six hours. Small larvæ of *Culex pipiens* in fresh water succumbed to one part of copper sulphate in 53,500 of water in seventy-two hours and to one part of copper sulphate in 1,872 of water in eighteen hours. One part of copper sulphate in 4,400 of. water killed in forty-eight hours, while in another case two examples survived one part of copper sulphate in 308 of water for twenty-four hours.

The pupæ did not appear to be affected by the copper sulphate even in the large amounts except that it hastened development to the adult condition and in fully mature larvæ hastened the change to the pupal stage. In every case development was much more rapid in the experiment jars than in the check jars. Owing to this tendency to force development and to the irregular effect produced it is evident that the copper sulphate cannot serve as a practical larvicide.

It was noted that when a sufficient quantity of the copper sulphate was used, the water, both fresh and salt, was cleared up and a green precipitate formed at the bottom.

As the activity of the copper sulphate seemed greater in salt water, a solution to which sodium chloride—common salt—was added, was also tested. This was prepared by adding one ounce of sodium chloride to 120 cc of the copper sulphate solution used in the preceding experiments.

Experiment 8: with larvæ of all sizes and pupæ of *Culex pipiens* from pail cultures at New Brunswick. These were distributed in three jars of city water to which the combined solution was added as follows:

Jar 1—1 part of copper sulphate in 4400 of water.
Jar 2—1 " " " " " 2200 " "
Jar 3—1 " " " " " 1400 " "

Changes to pupa and the development of adults continued unchecked and seventy-two hours after the solution had been added

very few of the larvæ had been killed. The mixture was actually less active than the simple solution.

Experiments with Sulphate of Copper and Lime, or Bordeaux Mixture.

The solution used in these experiments was made by adding one ounce of copper sulphate to one and seven-eighths pints of water and to this sufficient milk of lime to make the mixture alkaline. The amount of water in the experiment jars was measured and thus the proportionate amount of Bordeaux mixture was obtained.

Experiment 9: with larvæ of *Culex pipiens* breeding in pails at New Brunswick. They were placed with the breeding water in two jars and enough of the mixture was added to give the following:

Jar 1—1	part of Bordeaux mixture in	82 of water.
Jar 2—1	" " " " "	24 " "

Forty-two hours after the addition of the Bordeaux mixture most of the larvæ were dead in Jar 1, nearly all were dead in Jar 2 and what remained were inactive. After sixty-six hours two larvæ were yet alive in each jar and, after ninety hours, there being no further change, the experiment ended.

Experiment 10: with larvæ and pupæ of *Culex pipiens,* breeding in a lot puddle at New Brunswick. They were placed in four jars of city water with some food material and some of the breeding water; enough Bordeaux mixture being then added to give the following proportions:

Jar 1—1	part of Bordeaux mixture in	1560 of water.
Jar 2—1	" " " " "	780 " "
Jar 3—1	" " " " "	390 " "
Jar 4—1	" " " " "	195 " "

Twenty-four hours after the addition of the Bordeaux mixture many larvæ had pupated and many adults had emerged. There were many dead larvæ in Jars 1 and 2, and most of the larvæ were dead in Jars 3 and 4. After forty-eight hours more larvæ had pupated and many more adults emerged. Several active larvæ were in Jars 1 and 2, but none were left in Jars 3 and 4. After ninety-six hours many more adults had emerged; there were several larvæ and pupæ in Jars 1 and 2, but nothing was left in Jars 3 and 4.

It is to be observed that in these experiments as in those with the copper sulphate much development from larva into pupa and

Figure 39.

Choked swamp areas where *Culex sylvestris* and *Anopheles* breed. The upper figure shows Mr. Seal at work determining what species occur. (Original.)

from pupa to adult, took place after the addition of the Bordeaux mixture, and that the killing was irregular, hence was apparently indirect. It is evident from these facts that the material cannot serve as a practical insecticide.

The experiments just detailed bear out Mr. Dickerson's conclusions and these are not really opposed to the statements made by Messrs. Moore and Kellerman in the Bulletin above cited. They state, page 16, that "Mosquito larvæ die at a concentration varying from ten thousand to two hundred thousand." The weakest effective solution we found was one to fifty thousand, and that was utterly unreliable, while not a mature larva or pupa was killed at any strength. On page 24 the authors state: "The use of some such method for the destruction of mosquito larvæ also seems worthy of attention. The mere removal of the great mass of algal growths in stagnant pools undoubtedly reduces the number of larvæ by destroying this source of their food and depriving them of protection from fish and other enemies. This is probably the explanation of the reported decrease in the number of mosquito larvæ after spraying a lily pond with Bordeaux mixture, although it is possible that the strength of the solution used may have been partly responsible for their death. It is believed that it will not be impracticable to use the amounts of copper sulphate necessary to actually destroy such larvæ. Certainly this method, if effective, offers considerable advantages over any now in use and should be thoroughly tested."

It will be observed that the authors make suggestions only and no direct statements of fact, and they give what I believe to be the true action of copper in the suggestion that it deprives the larvæ of food. It will be observed, if the chapter on the food of mosquito larvæ is consulted, in comparison with the tables in the copper Bulletin, that practically all the forms determined by Mr. Parker succumb quite readily to the copper sulphate. If, then, the mosquitoes depend upon this food to so large an extent that they must starve without it, we can readily account for the slow dying off in our experiments. The New Brunswick city water, it is fair to say, is decidedly poor in quality and rich in algæ. The breeding water in the pails was always more or less foul and the lot and gutter pools were not nice. Therefore in all the experiments the amount of wriggler food was present in great abundance. It is probable, also, that the copper exercised a toxic effect through the stomach and that would explain why the young died first. It also gives a reason for its failure to affect full fed larvæ and pupæ. It is possible that in some areas where there are no fish the copper sulphate may have a place, but at one to fifty thou-

sand the material is fatal to many fish and harmless to most larvæ, hence the results of the application might be contrary to what was intended.

Salt to check breeding in fresh water areas was tried because in many places water barrels and casks are placed on bridges and trestles by railroad companies and others to provide material for putting out fires. Fire buckets partly filled with water are also placed in the halls of hotels, and all of these furnish excellent breeding places for *C. pungens* and *restuans*, as well as, occasionally, some other species. If the simple addition of salt would prevent breeding it would be easy to secure its addition to the water on the double pleas that it would keep off mosquitoes, add to the effectiveness in fire fighting and retard freezing in winter. Unfortunately, while the salted pails were not so readily selected for oviposition, yet, unless the salting was very heavy, they did appear in small numbers. On the other hand, the addition of salt to water in which larvæ were already present exercised no bad influence upon them. They simply matured a little faster.

Lime is another common, easily obtained and cheap material and its general sanitary effect is desirable even if as a larvicide it is not quite so active as some others. I found that in pails and tubs into which a lump of lime was thrown, the water would stand for weeks without becoming infested by wrigglers, while neighboring pails were swarming, and I have often observed that in old lime buckets where there was an icing of lime over the surface no larvæ were ever found. Lime then, used freely in the barn yard and in offensive or muddy pools will sweeten the surroundings and check mosquito breeding to a very considerable extent. It will not answer where there is much addition of water and it must be used in considerable amounts to be effective.

Chloride of Lime is much more active and even so small a quantity as fourteen grains in one quart of water will kill all stages except pupæ ready to transform in a few hours. This makes an excellent material for treating gutters and drainage ditches. It should be finely divided for this purpose and should be spread or dusted freely over the surface. Used as it is ordinarily applied for disinfecting purposes, it is quite sufficient to destroy mosquito larvæ.

It will be noticed on reading over this section that there are really two different types of materials that are used as larvicides; those that make a film on the surface through which the larvæ and pupæ cannot safely penetrate to breathe, and those which mix with the water itself and either poison it or destroy the food of the larva. Each type has its advantages and its limitations. The

advantage of the oils that form surface films and do not mix with the water is that it is easy to determine the amount needed, and that for a given area it is always the same whether the pool is deep or shallow. Another point in their favor is that the action is as positive against pupæ as against larvæ. The disadvantage is the ease with which a film is destroyed and the short time that is needed to form a good breeding place after the application is once made.

The advantage of those materials that actually poison the water is that the latter is rendered unfit for larvæ so long as it remains or is not materially diluted. The disadvantage is that as a rule they do not act promptly or at all on the pupæ.

Phinotas oil and the *soluble crude oil* belong to both types and should be, theoretically, the best of all. But both are too destructive to aquatic life generally, where such exists, and are not as active disinfectants as some of the Cresol preparations for gutters, etc., besides being dirty.

Conditions vary, and no two can be dealt with in just the same manner. There are plenty of tools to work with and that should be selected which fits best.

At the risk of repetition, I will say again, that wherever permanent work is possible, these larvicides and their applications should be regarded as makeshifts only, until the more radical improvements can be made.

REPELLANTS.

As there are yet some mosquitoes in New Jersey, and as it may be necessary to go sometimes to places where there are a great many, it may be adantageous to know how they can be kept off, to a greater or less extent at least. There are some fortunate persons whom the insects seem for some reason to avoid, and as the exemption may be due to some peculiarity of personal odor, he that is subject to attack attempts to hide the source of that attraction behind some strong smelling oil or smoke.

Tobacco is a well known refuge for the afflicted, and he who is able to keep himself surrounded by a cloud of smoke from a cigarette, cigar or pipe, may sit comfortably on a Barnegat hotel piazza in the evening, provided he does not wear low shoes.

For those to whom this refuge is denied there are the Chinese and Japanese punk sticks or mosquito cones of various sorts; all burning slowly and forming an aromatic smoke that is really a considerable protection. In the compositions made up into cones or pastilles, napthaline and pyrethrum usually enter as the chief

ingredients, and both of these are of some effect. A friend who lived in a Florida town during one of the yellow fever epidemics assured me that he took no precautions save to have his pockets constantly filled with napthaline crystals and his rooms reeking with the odor of napthaline. This was before a mosquito was recognized as the carrier of the disease, and the explanation that occurs at this day is that the odor of napthaline kept mosquitoes from biting.

After learning of the effectiveness of the Datura smoke, some preparation forming a smoldering mass may be produced that will be more effective than anything heretofore used.

Of decoctions to be smeared upon face and hands when going fishing along shore or in the north woods there used to be a great number, each a little worse than the others and nearly all of them worse than the disease. Twenty-five years ago oil of tar mixed with a little olive oil was the favorite in the Adirondack region. Then came oil of pennyroyal, which was hardly less offensive, and then a mixture of the three, oil of tar, oil of pennyroyal and olive oil, which I used for years.

In 1896 or 1897 a correspondent who saw this formula in my "Economic Entomology," suggested that I try oil of citronello as a substitute. I did so, found it satisfactory, published the fact whenever I had a chance and now its use is almost universal. Along the boardwalks at night and on hotel porches along shore everywhere, the odor of citronello is noticeable.

Oil of citronello is an extract from a grass, *Andropogon nardus*, primarily used in the manufacture of a cheap grade of perfumery. The odor is not unpleasant to most persons, is quite lasting and absolutely keeps off all kinds of mosquitoes. Protected by this material I have slept comfortably for an hour on an Anglesea piazza on an evening when everyone else was driven indoors. I have used it since 1897 on all my collecting trips, and no matter how large the swarm of mosquitoes surrounding me in the salt or other marshes or in the woods, none ever alighted on any protected part of the body. It may be liberally applied to hands, face or other exposed parts of the body, but should be kept out of and well away from the eyes. When the temperature is not excessive and there is little or no perspiration the material retains its effect an hour or more and causes no unpleasant skin sensation. When the temperature is high and perspiration is free, necessitating the use of a handkerchief, half an hour is the limit, and there is a more or less well marked burning sensation. At such times care should be taken to prevent the perspiration from getting into the eye, as the smarting caused by citronello in that organ is intense. It can be readily relieved by

washing; but in this case emphatically prevention is better than cure.

There are a large number of proprietory materials sold under all sorts of names at good stiff prices, advertised to keep off flies, mosquitoes and other pests, but none of those that I have tried have equalled the oil of citronello.

One of my correspondents advises me that he used this material on his horse during a stay along a salt marsh with excellent effect; but as a rule, a less expensive if more offensive mixture will serve here, i. e., fish oil with a little crude carbolic acid. Some of the preparations sold to keep off flies act fairly well to protect cattle from mosquitoes and, incidentally, it should be noted that the actual money loss to dairymen in the lessened flow of milk resulting from fighting mosquitoes would go a long way toward wiping out the dangerous breeding areas.

CHAPTER IV.

THE MOSQUITO CAMPAIGN.

a. PARTIES TO THE MOSQUITO CAMPAIGN.

Assuming that everything that I claim to have demonstrated be conceded, and that it be fully accepted that mosquito control and practical extermination is possible, an important question is, who is to do the work? Preliminary to that, assuming it to be a State matter, it might be justly asked whether New Jersey could, by itself, deal with the pest within its own limits, so as to get the full benefit of all the work that it might do. The answer to that question is, emphatically, yes; except for a short stretch along the Arthur Kill, where the Staten Island shore is bordered by a series of marshes that are as pestiferous from the mosquito breeding standpoint, as anything that we have in New Jersey. The Kill is so narrow that it is absolutely no bar to the transfer of species from one side to the other. An east or south wind will carry the Staten Island swarms into Elizabeth; a west or southwest wind will overwhelm Staten Island from the New Jersey supply; hence nothing that Elizabeth can do will prevent an occasional invasion from Staten Island. The matter is not equally

bad along the entire border, because toward the south the shores of the Island become much higher and there is no shore marsh. Except along this short stretch the State of New Jersey is safe from foreign mosquito invasion. From Sandy Hook to Cape May Point the Atlantic Ocean forms a perfectly safe area, east and south winds being absolutely safe. Delaware Bay is too wide to be safely crossed in a single flight by even the salt marsh species and as the shores of the river approach, the breeding area disappears. North of the Bombay Hook Island, on the Delaware side of the river, no salt marsh breeding places exist, but on the Jersey side the danger points extend to the Alloway Creek. No species that breed north of the points mentioned have the ability to fly across the Delaware River, hence it is safe to say that neither Delaware nor Pennsylvania sends any mosquitoes into New Jersey. Along the New York boundary to the north and northeast few mosquitoes occur on either side, and where they do, the trouble is local; none of the species is migratory. Along the Hudson River there are no salt marshes and none of the species that breed on the east shore of that stream can fly across it into New Jersey. As the river widens into New York Bay, the Long Island shore comes into account, but this is safe from the migratory forms until Gravesend Bay is reached. Though this has the typical marsh fauna, the full width of the widest part of Staten Island intervenes before the Jersey shore is reached, and the Island is quite capable of holding all the specimens that reach there from Gravesend or Coney Island. Except for the short stretch along the Staten Island side of the Arthur Kill therefore, the State of New Jersey is safe from foreign mosquitoes, and will obtain the full measure of exemption due for whatever work is done.

The first step in any campaign is local in any case, and begins with the individual. No person should tolerate any breeding place of any character on premises owned or controlled by him or her. The Duffield amendment to the State Health Law, passed during the session of 1904, places waters or pools in which mosquito larvæ breed among the nuisances that may be abated by local boards of health. I have shown that the larvæ of *Anopheles* breed almost anywhere and are liable to occur in any sort of pool where mosquitoes can breed at all. Hence every breeding place is a potential source of danger to health and the local board is rightly to be charged with the duty of caring for local conditions. Its power ceases, however, when the political limits for which it is appointed are reached and all breeding places beyond these limits are beyond its control. It can only notify

the board that has jurisdiction in the danger area and request that it take action.

Under the law as it stands the owner of the property on which the nuisance is situated can be ordered to abate it; if he fails to do so, it may be abated by the Board and the amount recovered from the owner.

The State Board of Health has general jurisdiction within the State, concurrent with local boards and in some cases its jurisdiction is exclusive. It has no power to compel local boards to act, but as it has all the powers of the local boards it may, in case of necessity, compel the abatement of a nuisance for the benefit of the community at large. So far as local conditions go, this machinery, though a little clumsy, would work satisfactorily provided a determined effort be made, but there is nothing that makes it compulsory for the State Board to interfere in local matters and the local boards have no right to demand action from the State Board.

Matters become complicated, however, when the source of the mosquito trouble is miles away from the point where the nuisance exists, and where property and other interests are imperiled. In some parts of Atlantic County mosquitoes are so bad at times that even the Italian berry pickers refuse to work, entailing serious loss upon the growers, and, in the pines, many a family has been literally driven out by them. Lakewood in the Pines is well known for its beautiful location and natural advantages, but there are many other places in the pine belt, equally accessible, equally beautiful and equally available for either a summer or winter resort. But the marsh mosquitoes are the bane of all these localities, and land is held at from 50 cents to $5.00 an acre.

None of these localities can help themselves, however willing they may be to do so. Nor can the owner of the marsh lands, which often produce no revenue, be reasonably required to expend more money than the lands are worth to put them into such condition that they will not breed the mosquitoes that annoy a population miles away. Some jurisdictions have more acres of marsh land than they have inhabitants, and breed mosquitoes enough to supply as many square miles as they have acres, and to impose a duty of drainage upon such a community where the benefit would accrue to outsiders chiefly, would be unjust.

The truth is that the matter of dealing with the salt marsh or migratory mosquitoes is a State problem. Only the State has universal jurisdiction; only the State can compel co-operation, and the State owes a duty to the large community living within the range of these salt marsh forms. It is not suggested that

the State should assist the wealthy shore communities in ridding themselves of the pest within their own jurisdiction, but it should make some provision for helping out those communities that are willing to help themselves. This might be done in part by providing a means by which any community could have its breeding places located, the source of its mosquito supply determined and the method of getting rid of them indicated. It might also assist directly, by providing for the payment of a certain percentage of the cost whenever the localities affected have raised a specified amount or proportion of the needed sum. In some such way the State must assist, and if it will also provide for a method of compelling the drainage or filling of areas that bar the way to a complete piece of work the days of the mosquito pest may be said to be numbered.

b. BOARDS OF HEALTH IN THE MOSQUITO CRUSADE.

As a rule I have found ready assistance from local Boards of Health in my efforts to obtain local information, and in most of these communities in which active work has been done, the members of the Board officially and often individually, have urged and supervised it. This is notably true of Newark and other Essex County Boards and it seems proper that the fight against this pest should belong to the sanitary authorities.

It is recognized by the medical profession at large that the species of *Anopheles,* because of their relation to malaria, are dangerous to the public health, and in this view places in which such species breed might fairly be considered nuisances subject to abatement under the general powers of the Board. But it was considered questionable whether breeding pools for other mosquitoes, no matter how annoying or indirectly dangerous they might be, could be brought under the same heading and, in every case of an attempt to abolish a pool of that kind, the burden of proof would be on the Board of Health to show that the mosquitoes bred there were really dangerous to the public health. In consequence, Boards were slow to act and fearful of attempting coercive measures which might not be upheld by the courts. At Newark a marsh owner refused to allow his land to be drained even at no expense to himself, and it was considered by counsel that the Board could not safely go ahead without being open to a charge of trespass.

At a meeting of the mosquito conference at Newark this matter was fully discussed and was referred to the legislative committee with Dr. T. N. Gray, of East Orange, as chairman, to prepare

Figure 40.

Meeting of a section of the Conference Committee on Mosquitoes at the rooms of the Newark Board of Health. * * * * At the head of the table is Dr. F. W. Becker, the President, of Newark; at the left of the table, beginning at the head, Mr. Louis J. Richards, Secretary, Elizabeth; Dr. T. N. Gray, East Orange; Prof. John B. Smith, New Brunswick; Mr. E. S. Gilbert, Bloomfield; at the right, beginning at the head of the table, are Mr. D. D. Chandler, Newark; Mr. Eugene Winship, Monmouth Beach; Mr. J. B. F. Grady, West Orange; Mr. Spencer Miller, South Orange, and Mr. J. B. Thomson, Arlington.

and present to the Legislature such an act as would give local Boards of Health the necessary powers to deal with mosquito breeding places as such.

After consulting with counsel it was determined that all that was needed was a slight amendment to the organic law under which local Boards of Health are empowered to act, and the words, "water in which mosquito larvæ breed," were introduced in sections 13 and 14 of the organic law, wherever the powers of such local boards were specified.

The bill proposing this amendment was introduced by Mr. Duffield, of Essex, and became known as the Duffield Act. It passed both houses and was approved by the Governor, forming Chapter 119 of the Laws of 1904. The full text of the law as it stands at present is as follows:

AN ACT to amend an act entitled "An act to establish in this state boards of health and a bureau of vital statistics and to define their respective powers and duties," approved March thirty-first, one thousand eight hundred and eighty-seven.

BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey:*

1. Sections thirteen and fourteen of the act entitled "An act to establish in this state boards of health and a bureau of vital statistics, and to define their respective powers and duties," approved March thirty-first, one thousand eight hundred and eighty-seven, be and the same are hereby amended to read as follows:

13. Said local boards shall, within their respective jurisdictions, examine into all nuisances, foul or noxious odors, gases or vapors, water in which mosquito larvæ breed, and all causes of disease which may be known to them or brought to their attention which, in their opinion, are injurious to the health of the inhabitants therein, and shall cause the same to be removed and abated; whenever such nuisance, noxious odors, gases or vapors, water in which mosquito larvæ breed, or cause of ill health or disease shall be found on public property or on a highway, notice shall be officially given by the said board to the person in charge thereof officially, and such persons shall be notified to remove and abate the same; and if there be failure or neglect to comply with such notice, the mode of procedure shall be the same as is hereinafter provided in case of private individuals.

14. Where such nuisances, noxious gases or vapors, water in which mosquito larvæ breed, or cause of ill health or disease shall be found on private property, the said board shall cause notice

thereof to be given to the owner or owners to remove and abate the same at his own expense, within such time as the said board may deem proper; a duplicate of the notice so given shall be left with one or more of the tenants or occupants of the premises; if the owner resides out of the State or cannot be reached with notice speedily, notice left at the house or posted on the premises shall be deemed sufficient, and if the owner or owners thus notified shall not comply with such notification or order of the local board of health within the time specified, the board shall proceed to abate such nuisance and remove the cause of such foul and noxious odors, gases or vapors, water in which mosquito larvæ breed, or other thing detrimental to the public health, and such board shall have a right to recover by action of debt the expenses incurred by such board in the abatement or removal, from any person or persons who shall have caused or allowed such nuisance, source of foulness, water in which mosquito larvæ breed, or cause of sickness, hazardous to the public health, and from any owner, tenant or occupant of the premises who, after notice as aforesaid, shall have failed to remove such nuisance, source of foulness, water in which mosquito larvæ breed, or cause of sickness, hazardous to the public health, within the time specified in such notice; and in case such board of health shall fail to recover by such action an amount sufficient to defray such expenses, or if it shall be deemed inexpedient to bring such suit, they may present a bill, certified by such board, or a majority thereof, to the local municipal authorities, and such bill shall be audited and paid by the city, borough, town, township or other local municipal government in and for which such board is organized, in the same manner as the bills for the ordinary current expenses for such municipality are paid.

2. This act shall take effect immediately.

Approved March 28, 1904.

It will be noted that the mere fact that mosquito larvæ of any kind breed in water of any kind is sufficient to give the boards jurisdiction, and that nothing else need be proved in a proceeding against an owner of land that holds such pools, in case he fails to comply with an order to abate. It is not even necessary for a local board to pass an ordinance declaring such breeding places to be a nuisance; but some boards have preferred to do this, and have made their proceedings and penalties for similar nuisances applicable to mosquito pools as well.

At any rate, as the law stands at present writing, every Board of Health in the State has an absolute power to compel owners

Figure 41.

Palpi or mouth feelers of male mosquitoes: 1, *Culex aurifer;* 2, *C. canadensis;* 3, *C. discolor;* 4, *C. cantans;* 5, *C. melanurus;* 6, *C. cantator;* 7, *C. signifer;* 8, *C. triseriatus;* 9, *C. atropalpus;* 10, *Janthinosoma musica;* 11, *Anopheles punctipennis.* (Original.)

of land on which there are mosquito breeding areas to abate the nuisance.

In another part of this report it will appear that a number of communities have already made good use of this amendment and it is safe to say that no greater step toward mosquito extermination has ever been taken in any community.

If every local Board of Health in the State were to use to the full extent the powers conferred in this amendment, no breeding places would remain in a year or two. It is safe to say that this will not occur, because, in the case of the salt marsh areas, the work necessary to make them mosquito safe would, in many cases, greatly exceed the present value of the land, on which the breeding places are found.

The existence of this law, however, tends to bring the Board of Health officers into contact with owners of dangerous areas and that will, in itself, work for a uniform and reasonably strict compliance with the law. The reports of Mr. Richards, of Elizabeth, and Mr. Allen, of South Orange, on a subsequent page, will show some special applications of the law and will indicate that for communities without the range of the salt marsh species a perfect machinery already exists which is ready to be put in motion whenever public sentiment demands it.

PART III.

Classification and Description.

CHAPTER I.

SYSTEMATIC ARRANGEMENT.

a. GENERAL CLASSIFICATION.

The family *Culicidæ*, or mosquito, belongs to that section of the order *Diptera*, or flies, in which the antennæ, or feelers, are long and many jointed. They are slender, long legged and narrow winged, of moderate or small size, and differ from all the other similar flies by the venation which is as figured and described on page 7. The fringing of scales is also peculiar, and that will be illustrated for the various genera where they differ sufficiently.

The family is broadly divided into two series: The *Culicini*, or true mosquitoes, which have long beaks covering lancets, meant for piercing or "biting," and the *Corethrini*, which are of stouter build and have no beak or lancets fitted for piercing or biting.

The *Culicini*, or true mosquitoes, that occur in this State are divided among seven genera, which are usually recognized without much difficulty.

1. *Anopheles*, in which the palpi, or mouth feelers, are long in both sexes, reaching to or exceeding the tip of the beak. The abdomen and body in general are slender, the legs long and thin and the wings more or less spotted. When at rest the body is held at nearly right angles to the surface and the hind feet are directed high in the air.

2. *Culex*, in which the palpi, or mouth feelers, are long in the male, equaling or exceeding the proboscis in length, and short in the female, not extending even to the middle of the beak. The body is stouter than in *Anopheles*, the legs are not quite as long

and the wings are not spotted as a rule. The few species in which they are maculate are recognizable by their small size, even without reference to the generic characters. When at rest, the body is held parallel to the surface, and the legs, though pointed upward, are not elevated nearly so high as in *Anopheles*.

The species here referred to *Culex* have been distributed among a number of subdivisions on various characters which are not readily seen without a compound microscope. I therefore leave them together here, but in the list of species refer them to their proper divisions, though I am not at all sure that these are correct associations in all cases.

3. *Janthinosoma*, in which the palpi of the male are very long and those of the female short; the disproportion in the sexes much greater than in *Culex*, which the genus otherwise resembles. The abdomen is more or less purple and the hind legs are black with the feet white. The resting position is as in *Culex*.

4. *Psorophora* contains the giant among our mosquitoes, recognizable not only by its size but by the erect scales on the legs, giving them the appearance of chimney cleaners on a small scale. The antennæ are rather short in both sexes. The palpi, or mouth feelers are long in the male, short in the female, and the position when at rest approximates that of *Culex*.

5. *Aedes*, in which the palpi, or mouth feelers, are short in both sexes; but the characters are otherwise much as in *Culex*, though the size is smaller.

6. *Uranotænia*, in which the palpi, or mouth feelers, are short in both sexes, the proboscis is swollen at the apex, and the thorax is ornamented with metallic blue scales.

7. *Wyeomyia*, in which the palpi, or mouth feelers, are short in both sexes and the proboscis is two-thirds the length of the body. The species is even smaller and slighter than *Aedes*, and when at rest the legs are held high in the air curved over the body and the tarsi recurved toward the head.

The three genera *Aedes*, *Uranotænia* and *Wyeomyia* each contain only one small species of a somewhat distinctive appearance, and, indeed, only *Anopheles* and *Culex* really have more than a single representative in our State.

The *Corethrini*, or short billed mosquitoes, that occur in New Jersey represent three genera.

1. *Sayomyia*, in which the palpi, or mouth feelers, are short in both sexes; the antennæ are somewhat beaded with whorls of hair to each joint, and the first joint of the tarsus, or foot, is longer than the second.

2. *Corethra*, in which the palpi and antennæ are as before, but

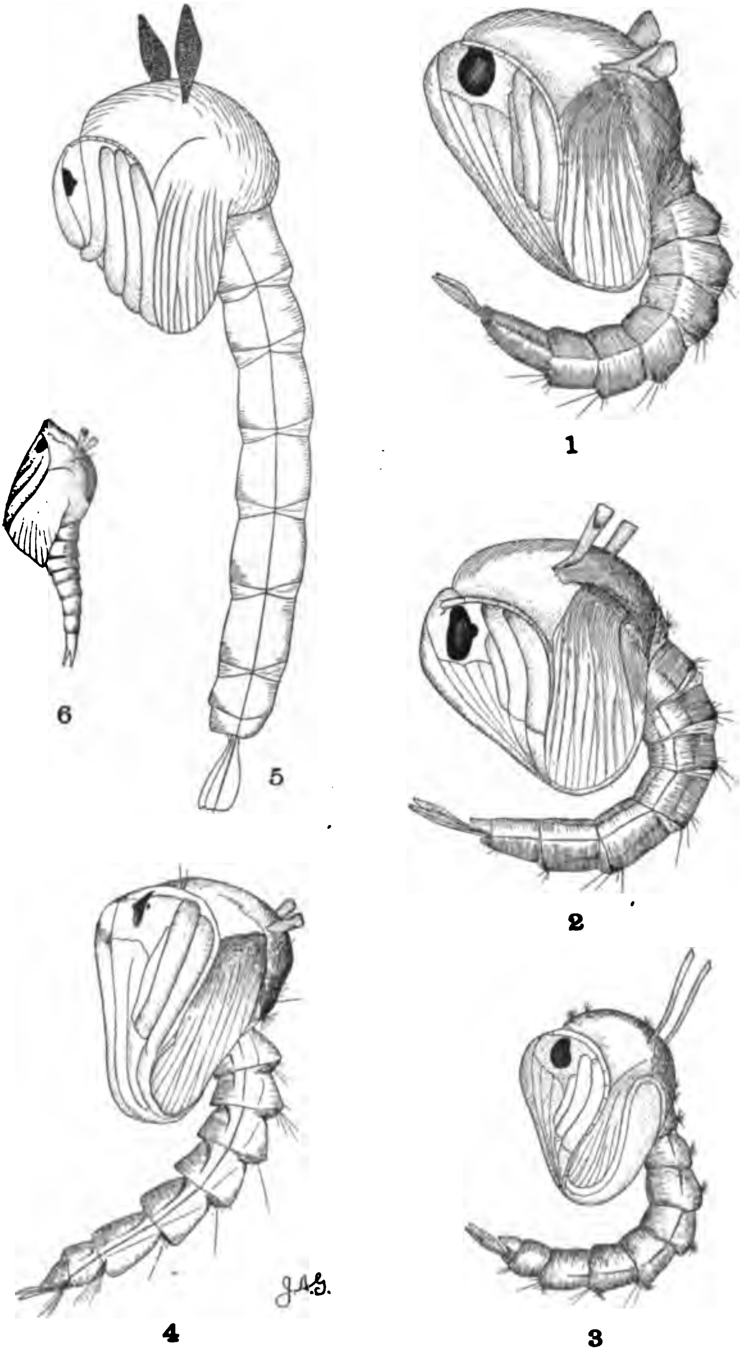

Figure 42.

Mosquito pupæ: 1, *Anopheles punctipennis;* 2, *Culex pipiens;* 3, *Uranotænia sapphirina;* 4, *Wyeomyia smithii;* 5, *Sayomyia albipes;* 6, *Corethrella brakeleyi.* (Original).

the first joint of the tarsus, or foot, is much shorter than the second.

3. *Corethrella,* in which the antennæ are evenly covered with hair, not beaded; the palpi, or mouth feelers are short in both sexes, and the first joint of the tarsus, or foot, is longer than the second.

The *Corethrini* are usually light yellow in color, have a somewhat humpbacked appearance and do not look like mosquitoes at all to the average observer. As they do not bite and are rarely at all abundant they do not attract attention nor do they need much consideration here.

b. TABLES OF THE SPECIES FOUND IN NEW JERSEY.

After the mosquito in hand has been placed in its proper genus, the work is done except for the members of the genera *Anopheles* and *Culex,* for in no other is there more than one New Jersey species. To facilitate recognition of the species of *Anopheles* and *Culex* they are arranged in the form of a synoptic table in which all those having similar characters are grouped together, as *e. g.,* those having the beak banded, or the legs banded, and the like. Other characters are then used to separate the species of each group until each species stands by itself as nearly as possible. By using this "table" or "key" the specimen may be usually identified, or if there remains a doubt, it will need reference only to a few descriptions to make certain.

TABLE TO DETERMINE THE SPECIES OF ANOPHELES

Palpi uniformly dark brown.
  Wings with two white spots on the front margin of the wing; last vein wholly white, ... *punctipennis*
  Wings with four distinct brown spots; last vein wholly dark brown, ... *maculipennis*
Palpi white marked at base of joints; last vein white, marked with three black spots, ... *crucians*

TABLE TO DETERMINE THE SPECIES OF CULEX.*

SERIES A, in which the feet are white or yellowish banded.
I. The beak has a more or less distinct white band or ring at or near its middle.
  a. The abdomen has a yellowish stripe down its middle, and the sides of the thorax are white below a black edging, ... *sollicitans*
  b. The abdomen has no longitudinal stripe; the sides of the thorax are not white.
    1. The wings are spotted, the body is mottled and variegated with brown, ... *discolor*

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* See figure 1, p. 15, for an illustration of the characters used in this table.

2. The wings are unspotted.
   x. A large blackish species with a narrow white band near the tip of the femur; the tibia white spotted, ... *jamaicensis*
   x1. A large brown species with a lighter band near the tip of the posterior tibia—the latter not spotted, ... *perturbans*
   x2. A smaller, blackish species, without markings on femur or tibia, ... *tæniorhynchus*

II. The beak is without band or ring; uniform in color.
  a. The joints of the feet or tarsi are banded or ringed at base only.
   1. A very large species, with very scaly wings; the sides of the thorax and the bands of abdomen and feet white, ... *squamiger*
   2. A small dark species, with lightly scaled wings; the white bands of the feet narrow; those of the abdomen nearly divided in the center, ... *sylvestris*
   3. A small brown species with the hind tarsi wholly white, ... *niveitarsis*
   4. A good-sized brown species, with the bandings yellowish rather than white, those on the abdominal segments only a little or not at all notched at the middle; breeds on the salt marshes only, ... *cantator*
   5. Very like the preceding; but the bands of the feet and abdomen are broader and somewhat lighter in color; breeds only in fresh water areas, ... *cantans*
   6. Very like the two preceding; but the thorax has a central brown stripe, ... *siphonalis*
  b. The joints of the hind feet at least are white-banded or ringed at both base and tip; while the last joint of the hind tarsi is entirely white.
   1. A good-sized brown species, the thorax without lines or marks, bands of the tarsal joints broad, ... *canadensis*
   2. A small blackish species, with the top of thorax covered with gray hair and a dark line down its center; the bands on the tarsi are narrow and white, ... *atropalpus*
   3. A small, blackish form, the thorax with fine, bluish longitudinal lines; only the hind feet are white-banded and the wings are mottled, ... *signifer*

SERIES B, in which the feet are uniform in color, not in any way marked or banded.

I. The thorax is marked in some way, with stripes or spots, or the sides are white or golden brown.
  a. Species with longitudinal white stripes.
   1. There are two white longitudinal stripes; the species is of moderate size and blackish, ... *trivittatus*
   2. There is a well-defined broad central white band, and the top of the head is also white; else as before, ... *serratus*
   3. There is a diffuse white central stripe, not defined as before; a very small blackish species, ... *dupreei*
  b. Species in which the thorax is yellowish, white or brown, leaving a blackish central stripe, usually not sharply defined; all of moderate size.
   1. The thorax is yellowish; the abdomen white-banded, ... *pretans*
   2. The thorax is brown, with pale yellowish scales; abdomen white-banded, ... *inconspicuus*

3. The thorax is golden brown; the abdomen not banded, ... *aurifer*
4. The thorax is silvery white at the sides, not extending much on the upper surface, most of which is black; the abdomen is not banded, ... *triseriatus*

c. Species in which the thorax is white-spotted only.

1. There are two small white dots on each side of the middle and a U-shaped white mark at base; the abdomen is banded, ... *restuans*

II. The thorax is without marks or ornamentation of any kind.

a. The segments of the abdomen are narrowly banded at their base.

1. A moderate-sized brownish species, with the bands of the abdomen of moderate width, ... *pipiens*
2. A somewhat darker, longer-legged species, with very narrow regular abdominal bands, ... *salinarius*

b. The segments of the abdomen are narrowly banded at their apex only.

1. A small, slight, blackish species, ... *territans*

c. The abdomen has no bands or only the merest indications of them.

1. A uniformly dark brown species of moderate size, ... *melanurus*

C. TABLE TO DETERMINE THE MOSQUITO LARVÆ FOUND IN NEW JERSEY.

1. Antennæ pendant from the front of the pointed head, with four long, curved apical spines,
   Without a siphon or breathing tube on the eighth abdominal segment, ... *Sayomyia albipes*
   With a siphon or breathing tube on the eighth abdominal segment, ... *Corethra cinctipes*
2. Antennæ not pendant, arising from near the center of the anterior part of the head and folding back against it; head very large; size very small; a siphon or anal breathing tube present, ... *Corethrella brakeleyi*
   Antennæ not pendant, arising from the sides of the head, ... 3
3. No siphon or breathing tube on the eighth abdominal segment, ... *Anopheles* 4
   A siphon or breathing tube on the eighth abdominal segment, ... 5
4. Antennæ yellowish; tracheal gills moderate in size, ... { *punctipennis* / *maculipennis* }
   Antennæ shorter, brownish; tracheal gills short, ... *crucians*
5. Hair tufts on thorax and abdomen simple, sparse, or absent, 6
   Thorax and abdomen with star-shaped or stellate hair tufts, ... *Uranotænia sapphirina*
6. Abdomen with four tracheal gills at tip, ... 7
   Abdomen with two tracheal gills only; a small whitish species, with head rounded and thorax subquadrate, ... *Wyeomyia smithii*
7. Antennæ arise from the sides of the anterior part of the head, ... 8
   Antennæ arise from near the middle of the sides of the head; the mouth brushes forming a club at the sides of the mouth; a very large species, ... *Psorophora ciliata*
8. The scales of the eighth abdominal segment are separate, .. 10
   The scales of the eighth abdominal segment, 5 to 8 in number, are arranged on a band, ... 9

The scales are replaced by a series of chitinous bars, arranged in a single row, ... 26
9. The anal siphon is very large and stout, dilated centrally; antenna much longer than head, slender, with an even outcurve or convexity, ... *Janthinosoma musica*
The anal siphon shorter, stout, dilated nearer the base; antenna nearly straight, slender, shorter than the head, ... *Culex jamaicensis*
The anal siphon is short, stubby, not dilated; antenna much longer than the head, very thick medially, bisinuate or with an outward and an incurve or convexity,..... *C. discolor*
10. The scales are not more than 15 in number and form a small patch, ... 11
The scales number 20 or more and form a large patch, ... 14
11. Anal siphon of moderate length; three times as long as wide, or longer, ... 12
Anal siphon short, less than three times as long as wide, ... 13
12. About 12 elongate scales in a single row; 12-16 siphonal spines, each with one moderate-sized tooth, and sometimes a few very small ones below it, ... *Aedes fuscus*
Scales 10-15, in a partly double row, tapering apically; siphonal spines 14-18, simple or with 2 or 3 teeth,.... *Culex sylvestris*
Scales 7-12, in patch; a small translucent species, feeding at bottom; tracheal gills very long and slender, ... *C. dupreei*
13. A stout black species, the thorax white-banded; antennal tuft composed of many hairs; tracheal gills very long, ... *C. serratus*
An elongate, slender, gray species; antennal tuft a single bristle; tracheal gills short, ... *C. triseriatus*
14. Anal siphon short, not much more than twice as long as broad, ... 15
Anal siphon moderate, from 2½ to 3½ times as long as broad, ... 17
Anal siphon long, not less than four times as long as broad, 23
15. Stout, compact larvæ; antennal tuft of several hairs, ... 16
Long, slender larva, antennal tuft of 1 or 2 hairs; 25-35 scales in patch; 17-21 siphonal spines with 2 or 3 long teeth at base, ... *C. atropalpus*
16. Scales 14-22, with stout apical and slender lateral spines; 13-18 siphonal spines with 2 or 3 small teeth, sometimes simple; fresh water, ... *C. trivittatus*
Scales 16-22, with rounded apex and slender lateral spines; 12-16 siphonal spines with 1-4 small teeth on both sides; head maculate; salt marsh, ... *C. tæniorhynchus*
Scales 20-40, with stout apical and slender lateral spines; 16-24 siphonal spines with 1-5 small teeth; head generally immaculate; salt marsh, ... *C. sollicitans*
17. Scales rather broad, ... 18
Scales elongate, ... 19
18. Scales 35-40, with 3 stout apical and smaller lateral spines; 16-20 siphonal spines with 1-3 small teeth; head maculate; salt marsh breeder, ... *C. cantator*
Scales 25-50, with one very stout apical and slender lateral spine; 16-22 siphonal spines with 1 or 2 large and 4-6 smaller teeth on basal half; head immaculate; fresh water form, ... *C. cantans*
19. Only the terminal segment with a dorsal plate or ring, ... 20
Last two segments, with dorsal plates; antenna very short, ..*C. signifer*
20. Antenna not specially marked or colored, ... 21
Antenna prominent, white at base, dark at tip, ... *C. aurifer*

21. Moderate-sized species, ... 22
Very large larva; scales 28-34, with long apical and slender lateral spines; siphonal spines 17-22, with 4 or 5 large teeth basally, ...*C. squamiger*

22. Scales 25-30, with short apical and very short lateral spines; siphonal spines 16-20, with 1 or 2 teeth at base, 1 usually very large, ...*C. pretans*
Scales 40-45, with 5-7 large apical and smaller lateral spines; 16-22 siphonal spines, with usually 1 or 2, rarely 3 or 4, small teeth, ...*C. inconspicuus*
Scales 45 (one larva), with small, slender, apical and fine lateral scales; 15-27 siphonal spines, with 1-3 large teeth; rust-colored marks on thorax, ...*C. niveitarsis*
Scales 25-50, with small apical and smaller lateral spines; 16-24 siphonal spines, with 4-5 serrations on basal half; antenna dark at tip, ...*C. canadensis*

23. Antenna arising from an offset, ... 24
Antenna not arising from an offset, tuft below the middle; scales 24-30, ...*C. siphonalis*

24. Antennal offset and tuft well above the middle, ... 25
Antennal offset and tuft below the middle; siphon of moderate length; tracheal gills rather long, ...*C. restuans*

25. Anal siphon of moderate length, sides a little inflated; tracheal gills moderately long, ...*C. pipiens*
Anal siphon very long, rather slender, tapering regularly to tip; head narrower than thorax; tracheal gills short, *C. salinarius*
Anal siphon very long and slender, a little constricted centrally; head as wide as thorax; tracheal gills moderate or long, ...*C. territans*

26. A bronzed brown larva with rather long, moderately stout black breathing tube, ...*C. melanurus*

Note concerning illustrations.—In all the plates showing larvæ the drawings have been made under the microscope, in large part from cast skins, for details. The result is that the anal siphons are, in almost every instance, too broad, and in any measurements one-fourth of the width should be deducted. The larval heads are also from cast skins. Except where otherwise credited, the original drawings are by Mr. Grossbeck, and on those figures credited to Mr. Joutel the adults only were drawn by him, the details supplied later by Mr. Grossbeck.

CHAPTER II.

DESCRIPTIONS OF THE SPECIES.

In the following descriptions the first paragraph is intended to present the combination of characters most readily seen with an ordinary hand lens. This is followed by a more detailed description, in which those structures that are used in technical classification are brought out, that students elsewhere may be under no misapprehensions as to which particular species is intended.

Information as to the habits of the insect follows, and this is based chiefly upon observations made by the investigation staff. Where it is otherwise, the authority is usually quoted. The observations were practically all made in New Jersey, and it should be remembered that local conditions in other sections of our country may cause local modifications of habit.

The descriptions of the larvæ are sufficiently full to render their recognition possible and their habits are set out in such detail as seemed needful in each particular instance. No effort has been made to describe each stage and no especial effort has been made to obtain eggs of other than the pestiferous species. Nor has the pupa been described in detail in any case, striking or unusual characters or habits only being referred to.

The description of *Culex canadensis* is given in greatest detail to characterize a typical species and, in general, whatever characters are not referred to in other descriptions, may be assumed to be like the same structures in *canadensis*.

THE SPECIES OF ANOPHELES.

Three species of *Anopheles* or malaria carriers, also called dapple winged mosquitoes, occur within the State limits—*punctipennis, maculipennis* and *crucians*. The first, *A. punctipennis,* occurs everywhere and is by far the most abundant species, especially in the more southern portions of the State. The second, *A. maculipennis,* is also found throughout New Jersey, but is much less plentiful than that previously named, and it is, on the whole, more plentiful in the northern and hilly sections of the State. The third, *A. crucians,* is rare except in Cape May County, where it seems to replace the others, and at Cape May City is abundant enough to be a nuisance. So far as I am aware, of these three the malaria carrying habit has been positively

proved against *maculipennis* only. In the regions where *punctipennis* is most plentiful the disease is practically unknown, and while within the range of *crucians* malaria does occur, it is by no means prevalent and *maculipennis* is also found there. As the species resemble each other in general habits one account will serve for all.

Habits of the Adults.

As compared with the *Culex* the species of *Anopheles* are distinguished when at rest by holding the body at nearly right angles to the surface upon which they find a place, the beak nearly touching it almost midway between the anterior and middle legs. In *Culex* the body when at rest is held parallel with the surface and the beak is directed forward or obliquely downward in front of the anterior legs.

All the species bite, and bite hard; the intense pain of the puncture lasting longer than in the case of most species of *Culex*. So also the swelling is usually greater, though this varies with the individual as in all other species. All the species sing, but they can scarcely be said to be deliberate in attack. Yet *crucians* is the readiest biter of them all and violates tradition by biting during the day. This is a matter of very great importance, because it has been heretofore believed that if the individual retired at dusk into a mosquito proof shelter and remained until after sunrise, there would be practical exemption from danger. The Italian experiments are all based upon this supposed habit of the malaria carriers. As to *A. maculipennis* I have no reason to doubt the correctness of the belief; as to *punctipennis* there are exceptions and I have seen the species in the afternoon on porches, but rarely; as to *crucians*, that bites readily from sunrise until 11 a. m. and from 3 p. m. until and after dark. It is more than probable that it will bite at any time during the day, given a victim in a cool and sheltered location. Were this species a carrier of the disease, there would be no escaping it except under purely artificial conditions. It is a fact, however, that *Anopheles* do not usually begin to fly or to seek food until dusk. As to the distances for which they fly there are no reliable observations or experiments that enable me to fix a limit. I have reason to believe that they may fly a mile or more, but equal reason to believe that they do not do so habitually. The local limitation of malaria epidemics to points close to breeding places and the practical exemption of large districts of even small towns in which the disease occurs annually, all point to the fact that the insect carriers remain by preference close to their place of

birth. But when the necessity of seeking food or a place to oviposit arises, it is not easy to put a limit on the distance which the insect will cover. As the eggs are always laid on the surface of the water, this fact exercises an influence on both the length of individual life and on the flight.

All of the species are house mosquitoes, i. e., they make a positive effort to get indoors, through screens, between windows and in other accessible and apparently inaccessible ways. They are as ingenious in this respect as *Culex pipiens,* and infest bedrooms in greater proportionate numbers. At New Brunswick at least 100 *pipiens* develop for one *Anopheles,* yet in 1903, when I looked after this point, I found almost or quite as many *Anopheles* in my bedroom as there were *Culex.* So, in house captures elsewhere, the *Anopheles* were always present in disproportionate numbers.

Hibernation is in the adult stage, and while the insects find plenty of shelter outdoors, it is nevertheless true that they prefer to get into buildings if at all possible, and preferably into cellars. *Anopheles punctipennis* is rarely seen at Lahaway in the adult stage, though Mr. Brakeley has taken a few in the rooms each season. Larvæ may be found more readily, especially late in the season; but they are by no means numerous. Yet in the cellars and out buildings of the house and cranberry sheds and among the stored crates, Mr. Brakeley took in one winter approximately 5,000 specimens! It is fair to assume that not all of the hibernating examples were captured, either. As some specimens begin to seek winter quarters in September and the start in spring is not made until May, some individuals have a life period of nearly or quite eight months. Only the females survive and none of them feed before they go into retirement. All the specimens dissected during the winter showed an empty alimentary canal and undeveloped ovaries. In the early winter the abdomens were plump and filled with a fatty mass; in the early spring the body had shrunken and the fatty mass had disappeared. Normally a specimen will retain its selected position all winter, hugging the wall closer as the weather is colder, extending the legs as it grows warmer, and not until the warm weather has fully set in is there any attempt at flight. In warm weather they fly readily, when disturbed, to some other nearby hiding place; in cold weather they may be picked off or will even allow themselves to drop to the ground. In a well warmed house specimens sometimes become active during mid-winter and may bite. I have been bitten in February under such circumstances in the station building, during daylight hours, though in a darkened room.

There is always a great winter mortality and comparatively a small proportion of specimens survive to reproduce. A general cellar fumigation in districts were malaria is prevalent would be of great benefit and would materially lessen the number of the late summer broods.

The life period during the summer has been incidentally discussed, and it is probably at least a month, under normal conditions. So the fact that a specimen may bite several times at intervals has also been referred to, and it is a necessity for the transfer of malaria that the same individual should bite first a person having the disease, and after a week's interval one who does not have it but is susceptible.

General Life History.

So far as we know the life cycle of the species occurring in New Jersey is identical, and the early stages are so much alike that it is all but impossible to distinguish them. Dr. Dupree tells me that he has found good characters in both eggs and larva; but they are observable only with the compound microscope and do not influence the habits in any essential way.

The eggs are laid on the surface of the water, singly or loosely grouped, so that they float on the sides in little masses among the vegetation in which they are laid. From fifty to seventy-five seems to be an average for such a mass, thought there may be either more or less. Sometimes, indeed, a larger mass is broken into fragments and small groups of five or six, or even a less number, are formed. The eggs are elliptical in shape, the ends pointed, though not quite alike, and at first view the color is black. Under the microscope they are seen to be quite prettily marked and sculptured, the upper side being almost covered by a clasping membrane which comes over from the side. The length is about three one hundreths of an inch, or less than one millimeter.

The eggs hatch in about forty-eight hours, and the larvæ when they first become readily recognizable are black or blackish, marked with white or whitish spots and bands—"specklebacks," as Mr. Brakeley calls them. They vary greatly and no two seem to be alike. Unlike the larva of *Culex,* that of *Anopheles* floats on the surface of the water and does not go beneath it unless seriously disturbed. There is a very short anal breathing tube and, altogether, the larva is quite different in appearance from its ally. This habit of surface feeding enables it to live in very shallow water, at the edges of pools and among masses

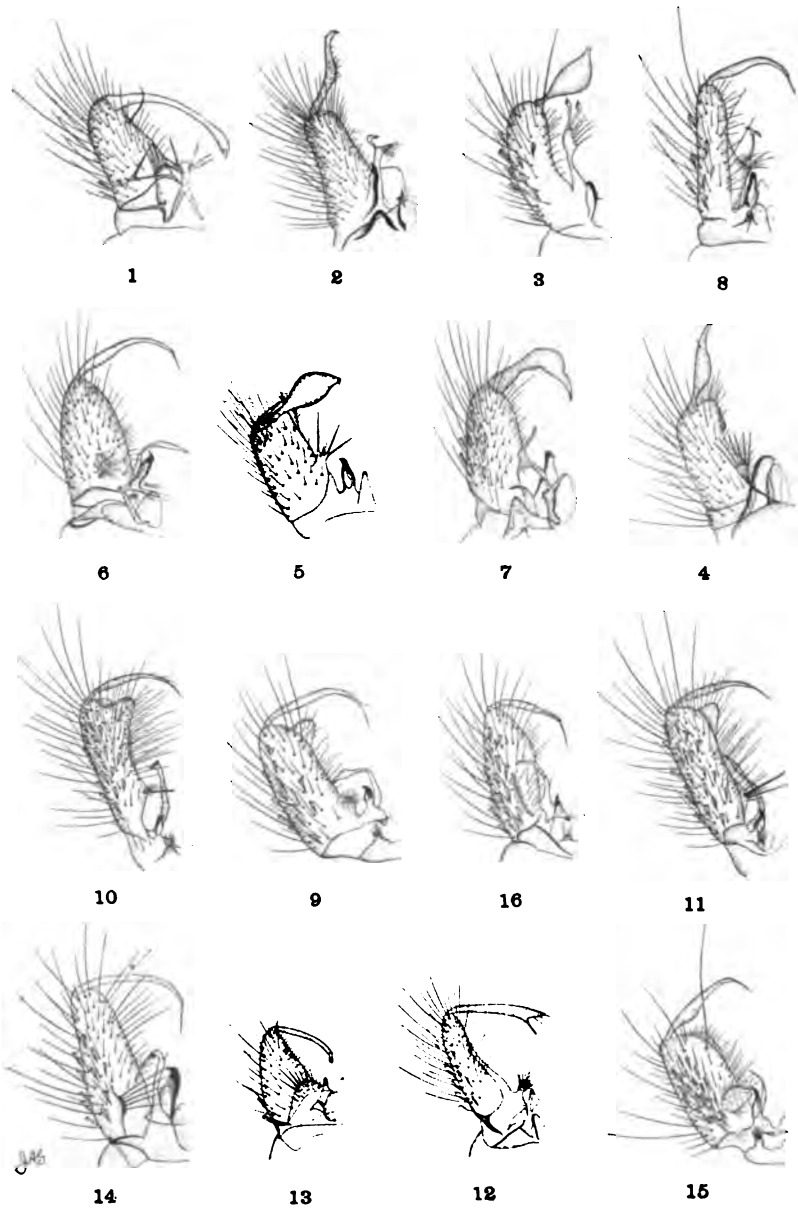

Figure 43.

Genitalia of male Culicids 1: 1, Anopheles punctipennis; 2, Psorophora ciliata; 3, Janthinosoma musica; 4, Culex jamaicensis; 5, C. discolor; 6, C. sollicitans; 7, C. perturbans; 8, C. tæniorhynchus; 9, C. squamiger; 10, C. cantator; 11, C. cantans; 12, C. sylvestris; 13, C. signifer; 14, C. atropalpus; 15, C. canadensis; 16, C. triseriatus. (Original.)

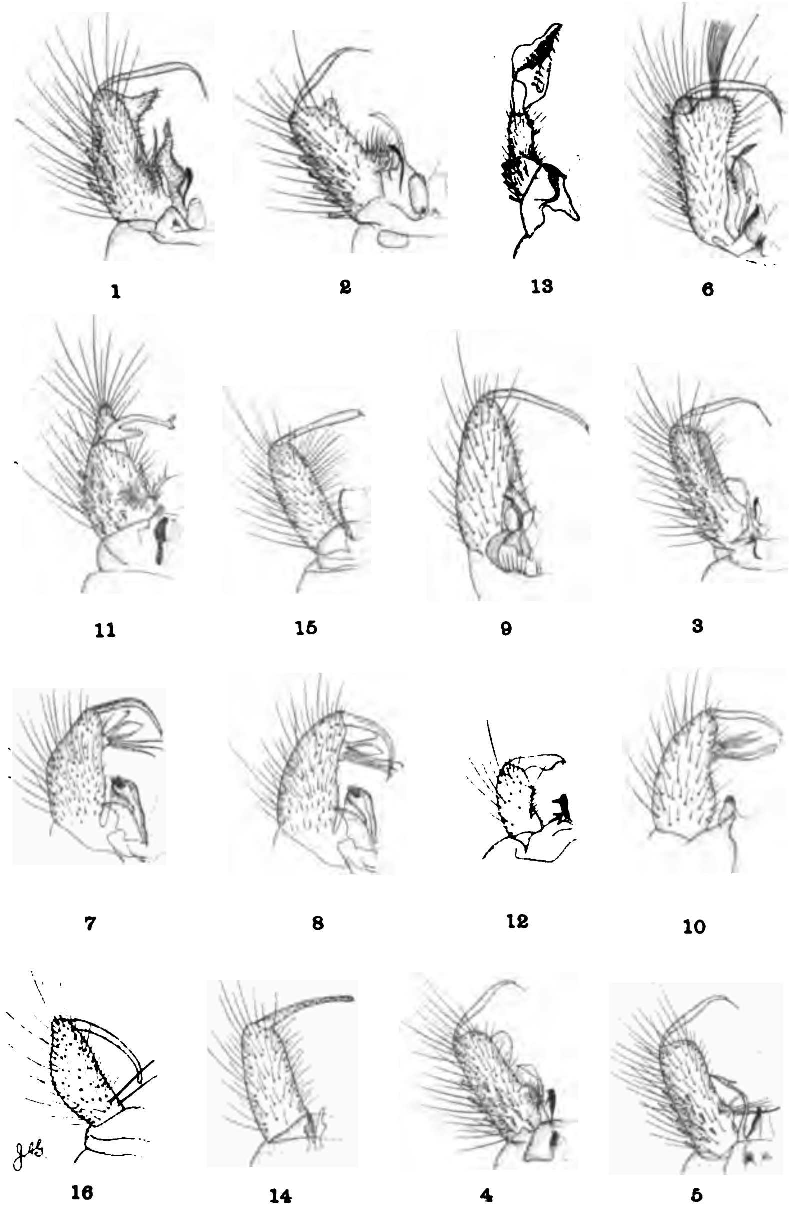

Figure 44.

Genitalia of male Culicids 2: 1, Culex serratus; 2, C. dupreei; 3, C. trivittatus; 4, C. pretans; 5, C. inconspicuus; 6, C. aurifer; 7, C. pipiens; 8, C. restuans; 9, C. melanurus; 10, C. territans; 11, Aedes fuscus; 12, Uranotænia sapphirina; 13, Wyeomyia smithii; 14, Sayomyia albipes; 15, Corethra cinctipes; 16, Corethrella brakeleyi. **(Original.)**

of floating vegetation—even over floating or partially submerged leaves, where it is safe from most aquatic enemies. The head of this larva is unusually movable and can be completely rotated; in fact the larva makes rather a practice of feeding with the bottom of its head at the surface of the water, while it floats otherwise naturally, back up. As the larva increases in size it tends to lose its speckled appearance and becomes more uniform, ranging from gray to black in one direction and to bright green in another. Mr. Seal considers this a protective character and finds a direct relation between the color of the larva and its habitation. He finds the green form over *Cabomba* and other green plants in the tubs, the darker ones in the fringe of brown or dark green *Confervæ* at the sides. How completely they are thus protected Mr. Seal records later: "I find we have been unsuspiciously fostering *Anopheles* in small ponds where we have fish. They are hidden so completely from the fish and are so difficult to observe among plants at the surface that they easily escape detection without very close scrutiny."

The length of larval life varies according to the season, but from seven to ten days in mid-summer may be considered normal. The early spring brood requires at least two weeks, and the larvæ found in October linger even longer in the laboratory—specimens taken outdoors in November have certainly been in that stage during most of October.

The pupa resembles that of *Culex*, but the abdomen is more sharply curved and the breathing tubes are much shorter, more dilated at the tip. The pupal period also varies according to circumstances; the shortest period—five hours—occurred in Mr. Brakeley's breeding, and in my own it has ranged from one to three days. As long a period as ten days has been recorded; but this must be rare.

As to the number of broods that occur during the season, it is impossible to speak definitely. Development is so irregular that in permanent breeding places all stages may be found at any time during the summer, and broods, strictly speaking, do not occur. When a female is ready she oviposits, whether her sisters of the same age are in condition to do so or not, and so we have a continuous development from early spring until freezing weather sets in.

Where Does Anopheles Breed?

This can be answered in one word—everywhere! I have had larvæ in the trap pails in my back yard and have found no

pool so insignificant nor stream too rapid but that somewhere in it *Anopheles* can breed. Nor need the water be either fresh or clean. The larva of *A. maculipennis* has been found on the salt marsh and I have taken that of *punctipennis* in a stream that was little better than an open sewer. Ordinarily the larvæ occur

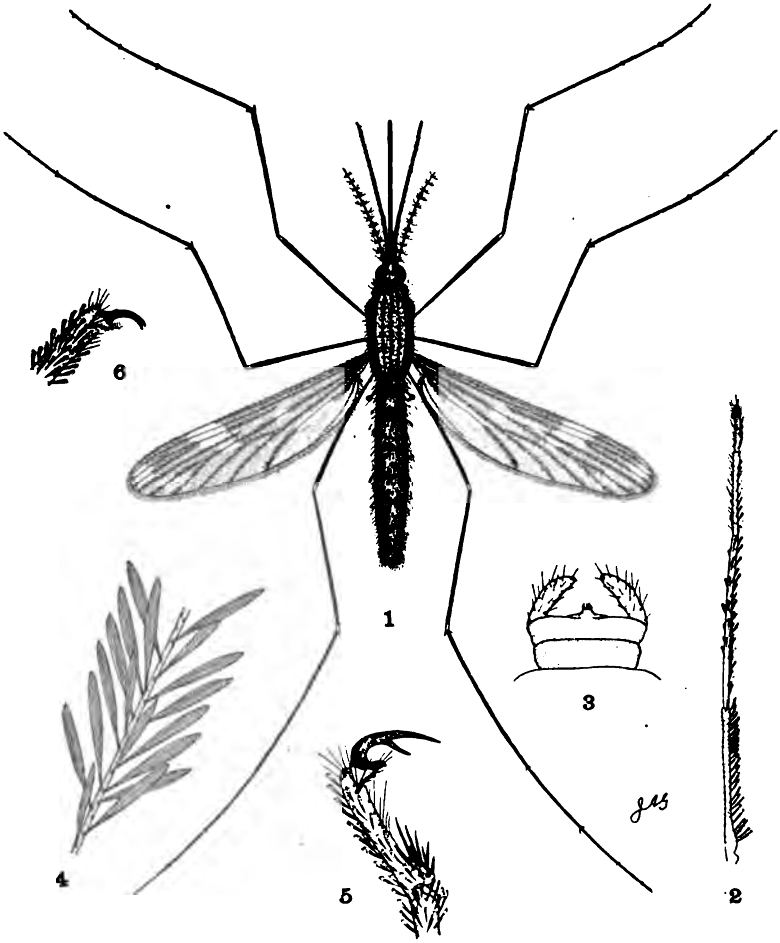

Figure 45.

Anopheles punctipennis; 1, female adult; 2, her palpus; 3, genitalia; 4, part of wing vein showing scales; 5, anterior and 6, middle claws of male: all much enlarged. (Original.)

singly, or in small numbers at one point; but occasionally they appear in numbers rivaling those of *Culex*. Small creeks through meadow land, the ditches and gutters or drains along railroad and other embankments, and the shallow overgrown edges of

ponds or swamp areas are favorite breeding places. Pools containing grassy or other vegetation are nearly always infested, and ponds with lily pads, dock, saggittaria and other plants of a similar character are danger points.

The larvæ need only a mere film of water, and this being found over a leaf or at a grassy edge, protects them from the usual natural enemies. This point has been elsewhere referred to and the practical bearing has also been discussed. It need only be added that no other mosquito has as wide a range of breeding places as have the species of *Anopheles*.

ANOPHELES PUNCTIPENNIS, SAY.

The Mottled Wing Anopheles.

A medium sized dark brown mosquito with the upper surface of the thorax dark brown at the sides and with several narrow lines of yellowish gray hairs appearing as one broad gray stripe in the center. The beak and legs are unbanded; the wings densely clothed with black and yellow scales, two large black patches and two smaller yellow ones on the front margin especially conspicuous. The abdomen is dark brown, profusely scattered with yellowish brown hairs.

Description of the Adult.

This species varies considerably in size and is of slight build. The body measures from 4 to 5.5 mm., = .16 to .22 of an inch in length, and the beak is just about half the length of the body. The head is dark brown, with yellowish white mixed with brown scales in the center of the occiput near the angle of the eyes, the posterior margin of the eyes with a faint yellow border and with a tuft of yellowish hairs between the eyes projecting forward over the head. The proboscis is uniformly dark brown. The palpi in the female (fig. 45, 21) are dark brown, with some pale yellow hairs at the extreme tip, long and slender, four jointed, the first joint swollen at the base, the second longest, each succeeding one shorter. The male palpi (fig. 41, 11) are dark brown, paler toward the apex, with long hairs on the central and tip of basal joint, three jointed, the basal joint very long, the apical two short and greatly swollen. The antennæ are dark brown in both sexes with the basal joint of the female paler.

The dorsum of the thorax is dark velvety brown at the sides, with four weak median stripes of yellowish gray hairs, arranged on elevated ridges, the dividing depressions being brown; pleura dark brown with a few scattered whitish scales. The legs are very long and slender, dark brown, becoming almost black on the tarsi, the femora are slightly paler beneath, and the knees and apices of the tibiæ have a distinct yellow dot. The claws of the anterior tarsal joint in the male (fig. 45, 5) are very unequal in size, the large claw with a median tooth and a projecting extension of the base which appears as a tooth, the small claw very short, and simple. The claws of the mid (fig. 45, 6) and posterior tarsal joints are equal and simple, the latter a little smaller than the median. In the female the claws are equal and simple on all feet. The wings are hyaline, with the veins covered with black and yellow scales in patches as follows: costa, basal two-thirds and central part of the outer third black, each end of outer third yellow; sub-costa, black; radius one, basal two-thirds and central part of outer third black, each end of outer third yellow; radius two, black at basal three-fourths, then yellow to the fork, remainder black except a small yellow portion at the wing margin; radius three, black, sometimes with a yellow portion near the wing margin; radius four and five black, except for a few yellow scales near the wing margin; media one and 2, black, divided twice by yellow before the fork and again at the central third after the fork; media three, black with central yellow portion; cubitus, wholly black; anal vein black with a yellow portion near the base. The maculation of the wing veins runs generally as given above, but is more or less variable; the yellow portions sometimes being much larger or reduced, and the yellow divisions on media one and two before the fork connecting in one broad patch.

The abdomen is dark brown with yellowish brown hairs evenly scattered over the entire surface; beneath it is also dark brown, paler at the base of the segments.

Habits of the Adult.

This species occurs throughout the State and is really our common form. It is, however, on the whole much more abundant south of the red shale line and is the dominant species throughout most of South Jersey. There is nothing at all peculiar or unique in its habits. It is readily recognized by the distinctly mottled wings and the large size, being the largest species in the State except for *Psorophora*.

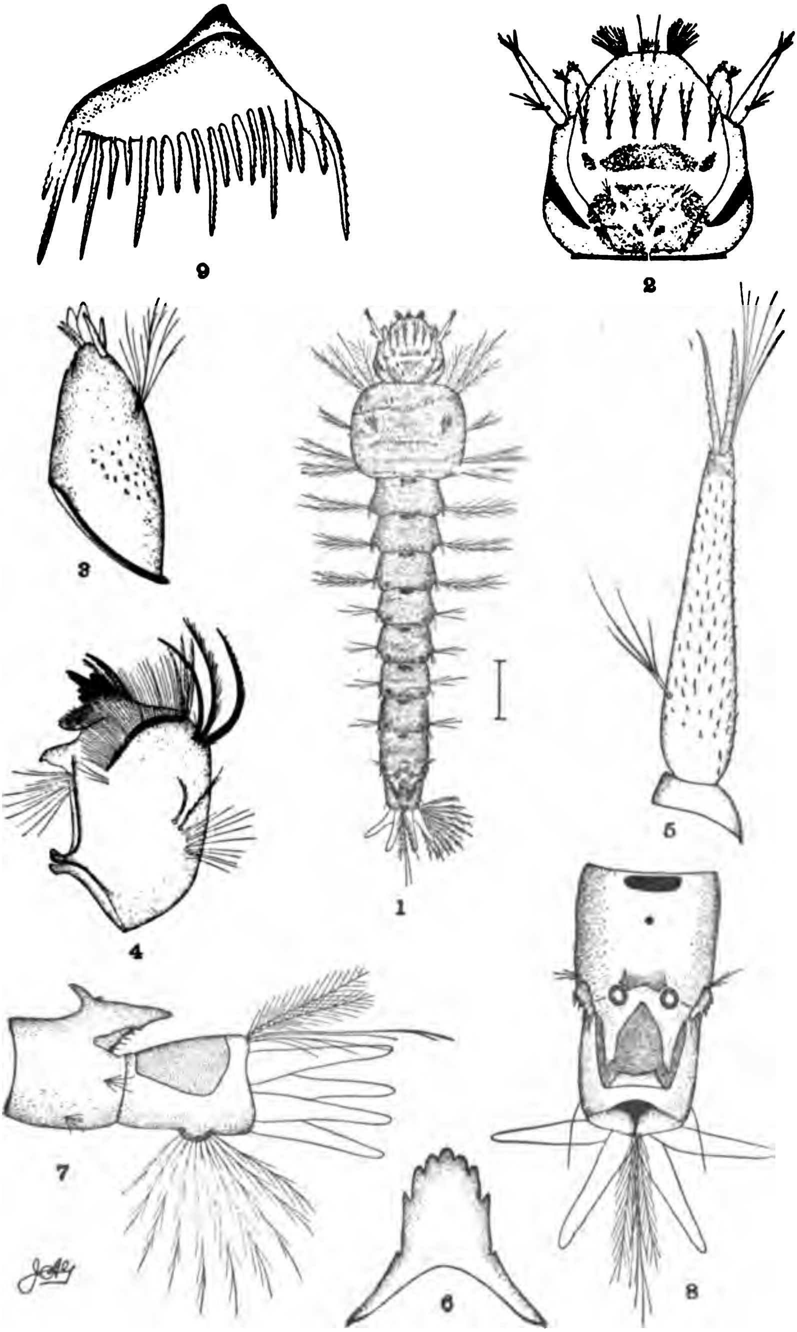

Figure 46.

Anopheles punctipennis: 1, larva; 2, head, above; 3, palpus; 4, mandible; 5, antenna; 6, mentum; 7, anal segments from the side; 8, anal segments from above, showing the two spiracles; 9, one of the scales: all greatly enlarged. (Original.)

Description of the Larva.

Structurally the larvæ differ greatly from those of *Culex*, possessing a very complex respiratory apparatus, adapted to their surface feeding habit. The full grown larva with details is illustrated on figure 46 and is 6 to 6.5 mm.,=.24 to .26 of an inch in length to the end of the ninth segment. The body of the young larva, exclusive of the head and chitinized parts of respiratory tube, is pale yellowish white, almost transparent save for the broad alimentary tract, which is dark gray or black; large larvæ are usually gray or brownish gray, but often clear pale green and only in the latter case is the alimentary tract visible. A longitudinal stripe, broken by the small dorsal plates, runs down the center of the dorsum and is usually white in color, rarely bright pink, and is narrow though widened at each of the segmental sutures. The head is rounded, as long as broad, with distinct offsets for the reception of the antennæ; pale yellowish brown in color with the basal half of the vertex maculate with brown as shown in figure 46, 2. There is some variation in size either way, or the smaller spots may be consolidated with the larger ones; but it is always well defined and seemingly very constant in form. This maculation is present also in young larvæ and of the same pattern. In the middle of the vertex, in a transverse row, are six rather long, equally spaced feathered hairs and several small, similar ones are situated farther back. The eyes are crescent shaped with a small spot in the concavity. The antenna (fig. 46, 5) is two jointed, the first very short, immovably attached to the head, the second comparatively long, thickest near the base, tapering evenly toward the apex and terminated by six long hairs and two spines, the latter serrated on one edge. The surface of the second joint is set with small spines, and a four branched hair representing the tuft, is situated on the shaft at about one-fourth its length from the base. The rotary mouth brushes are very small, but dense, and composed entirely of simple hair. The mentum (fig. 46, 6) is somewhat pentagonal in form, the two front angles with five large blunt teeth, the sides with two smaller pointed teeth, and the basal angles greatly elongated. The mandible (fig. 46, 4) is stout and chunky, with two large and several smaller teeth at the apex, and two spines below them which are serrated on their inner edge; on the dorsal surface are three large curved spines, one of which is simple, the others feathered on one side. A few of the hairs of the dorsal terminal part of the transverse fan are also branched. The maxillary palpus (fig. 3) is elongate, with four

stout spines and two lamellate processes at the apex, and at about one-third from the apex issues a stout hair which divides into a number of branch hairs.

The thorax is subquadrate, the angles rounded, each angle with three or four long feathered hairs, and two smaller simple hairs on each side between them; several similar, small hairs are on the dorsal surface.

The abdominal segments are transversely oblong anteriorly, becoming subquadrate posteriorly; the first two have each two long feathered hairs laterally, the third has but one;* the four succeeding segments have from two to four rather short simple hairs on each side, and very small simple and feathered hairs are at the base of the long hairs on all segments. On the dorsal surface, near the base of segments three to seven, are two small palmate hairs, and in the center, at the apical margin of segments one to eight, are small chitinized plates and sometimes extremely small circular dots below them. The eighth segment bears the respiratory apparatus; this is a very complex organ, which projects backward over the ninth segment as seen in the side view (fig. 7.) The tracheal tubes open on the dorsal surface of this structure by two stigmata, and immediately in front of these is a small plate which folds over the stigmata when they are not in communication with the outer air. Posterior to these openings is a large, partly chitinized squarish area, which comes in contact with the air when the stigmata are projected through the surface film. At each side of this apparatus is a triangular plate with from six to nine long teeth on the posterior margin and one to four short teeth between (fig. 9); usually there are about twenty in all.

The ninth segment is longer than broad, widest at the outer end and with the dorsum covered with a chitinized saddle which extends half way down the sides. The dorsal tuft is composed of two very long branched hairs and two shorter feathered ones; on the ventral surface is a semicircular process from which issue about nine long branched hairs with fan-like arrangement. The tracheal gills are fingershaped, blunt at the apex and slightly longer than the ninth segment.

Habits of the Early Stages.

There is nothing peculiar to this species in the development from egg to adult. The larvæ occur throughout the State wher-

* The drawing shows two hairs on each side of this segment; this is incorrect.

ever conditions favor and almost any body of water, large or small, clean or moderately foul, will serve to breed the pests. Nevertheless, on the whole it breeds most abundantly in clean water along the edges of ponds or swamp areas or in the eddies of shallow streams.

ANOPHELES MACULIPENNIS.

The Four-spotted Anopheles.

This is similar to *A. punctipennis,* but much lighter brown in color, and consequently the thoracic stripe, which is also more yellow, does not stand out so clear in contrast. The wing veins are clothed with brown scales, some of which gather into four very distinct patches a character which distinguishes it from all other species at a glance.

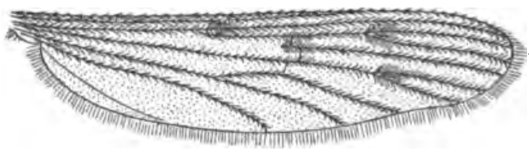

Figure 47.
Wing of *A. maculipennis:* enlarged. (Original.)

Description of the Adult.

This species, as in *punctipennis,* varies in size, but usually measures 5 to 6 mm.,=.20 to .24 of an inch in length, excluding the beak, which is about half the length of the body. The head is dark brown, with a patch of yellowish white scales in the center of the occiput, near the angle of the eyes, divided in the center by a line of brown scales; a tuft of yellowish hair projects forward over the head from between the eyes, and there is a faint border of the same color to their posterior margin. The proboscis is light brown; the palpi in both sexes are the same in shape as those of *punctipennis,* but light brown, paler toward their apices, and with the long hairs of the male yellowish. The antennæ are brown, the plumes of the male grayish brown.

The sides of the dorsum of the thorax are velvety brown, the intermediate area with three rows of yellowish hairs, the rows more or less divided by the brown ground color of the thorax.

This arrangement is best seen when held longitudinally on a level with the eye. The pleura and legs are the same as in *punctipennis*. The wings are hyaline; all the veins clothed with brown scales, and some darker ones collecting very densely in four parts of the wing as follows: one, on radius 1, at the cross vein where radius 2 begins; one each at the base of cell radius 2 and cell media 2, and another at the three cross veins, on radius 2, radius 4 and 5, and media 1 and 2.

The abdomen is the same as in *punctipennis*, but paler brown.

Habits of the Adult.

This species occurs throughout the State, but is decidedly more abundant northwardly. It also occurs in Europe, and is, perhaps, the most common of all the species which have been definitely convicted of transmitting malaria.

Description of the Larva.

The figures of *A. punctipennis* larva will serve for this species also. No differences between the larvæ appear in the alcoholic material, though it is probable that in living specimens the vestiture may have a slightly different arrangement.

Habits of the Early Stages.

In a general way, these agree with what has been already said concerning the other species. The breeding places are similar, but this form also occurs in brackish water on the salt marshes, hence has a somewhat wider range and adds the positive danger of disease to the disadvantages of an undrained marsh.

ANOPHELES CRUCIANS, WIED.

The Day-light Anopheles.

This is the smallest of the New Jersey species, though some specimens are as large as *A. punctipennis*. It is brown, not quite as dark as *punctipennis*, with the thorax striped with grayish scales, the wing veins clothed with whitish and black scales, the black ones especially collected along the wing margin.

Description of the Adult.

This species averages 4 to 5 mm.,=.16 to .20 of an inch in length, with the beak about half as long as the body. The head is dark brown with scattered yellowish scales at the angle of the eyes and a tuft of yellowish hair from between the eyes projects forward over the head. A narrow line of similarly colored scales forms a border to the posterior margin of the eyes. The proboscis is evenly dark brown. The palpi in the female (fig. 48) are the same in shape as the other species of *Anopheles,* but are dark brown in color, almost black, with the apical joint, base of the penultimate and of the antepenultimate joints white. The male palpi are dark brown with the long hairs toward the apex yellowish. The antennæ are dark brown in the female, paler in the male.

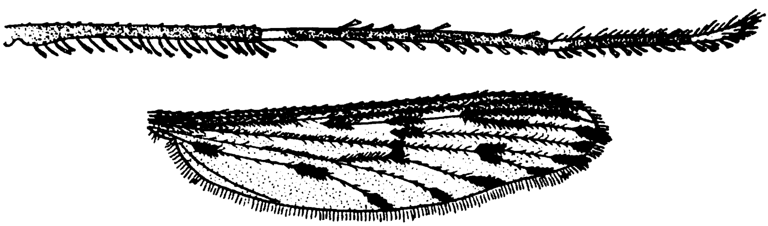

Figure 48.

Wing and palpus of female *A. crucians:* enlarged. (Original.)

The dorsum of the thorax is brown, mottled at the sides with grayish scales, and with narrow stripes of scales of the same color down the central part; the pleura and legs are the same as in *punctipennis,* but the latter are not nearly as dark. The wings are hyaline, with black, whitish and gray scales as follows: costa, black; subcosta, black; radius 1, black; a few white scales at extreme apex and some grayish ones just before the cross vein between radius 1 and radius 2; radius 2, black, broken twice with white portions before the fork and white again at the margin; radius 3, a large portion at base black, a smaller portion black at the margin, the intermediate part white; radius 4 and 5, black at the base and again at the margin, grayish and whitish scales between; media 1 and 2, grayish to the fork, with a small black patch at the cross vein, after the fork black at both ends, white between; media 3, black at both ends, white between; cubitus 1, white to the fork, then black to a little beyond the cross vein and again at the wing margin, the intermediate part white; cubitus 2, white, except a small black portion at margin; anal vein, white, a small black portion at each end and one in the center.

The abdomen, as in allied species, is dark brown with yellowish brown hairs evenly scattered over the surface.

Habits of the Adult.

Attention has been already directed to the fact that this species is not closely confined to the hours of darkness, but flies and bites freely long before dusk and long after sunrise. It bites quite as hard as either of the others and is as eager to get indoors. At Cape May, which is the only place where I have found it at all abundant, it is the most annoying indoor form and far more troublesome than *C. pipiens*. Isolated examples of the species have been taken at Lahaway, Delair and Port Reading, but the only real home of the species in New Jersey is Cape May County, and its chief breeding place is in the Cape Marsh, which is elsewhere referred to at some length.

Description of the Larva.

The larva of this species with details is illustrated at figure 49. It does not differ in general appearance from those of *A. punctipennis* and *A. maculipennies,* but is a little smaller, ranging from 5.5 to 6 mm., = .22 to .24 of an inch in length when full grown. In color it is dirty grayish brown, with the usual variation of the other larvæ. The white dorsal stripe may be present in living larvæ, but there is no indications of it in alcoholic specimens. The maculation of the vertex is variable, much larger than in the other species and with much less defined edges. The second joint of the antenna (fig. 3) is shorter and does not taper as much apically as in allied species, but is very blunt, with two long spines serrated on one edge and six long hairs, which have a common center; the color is dark brown, pale yellow at the base, with the surface set with rather long spines; the four branched hair larger and situated one-third the length of the antenna from the base. The mandible (fig. 5) and maxillary palpus (fig. 4) are of the normal *Anopheles* form, the former with four, instead of three, curved dorsal spines, three of them feathered on one side; the latter with the two apical processes spatulate in form. The dorsal plates on each of the abdominal segments are large and the circular spots beneath them very obvious. The respiratory apparatus is very similar to that of *maculipennis* and *punctipennis*. The lateral combs consist each of a large plate, the posterior edge with seven or eight long stiff spines and with ten or twelve shorter spines between them. The

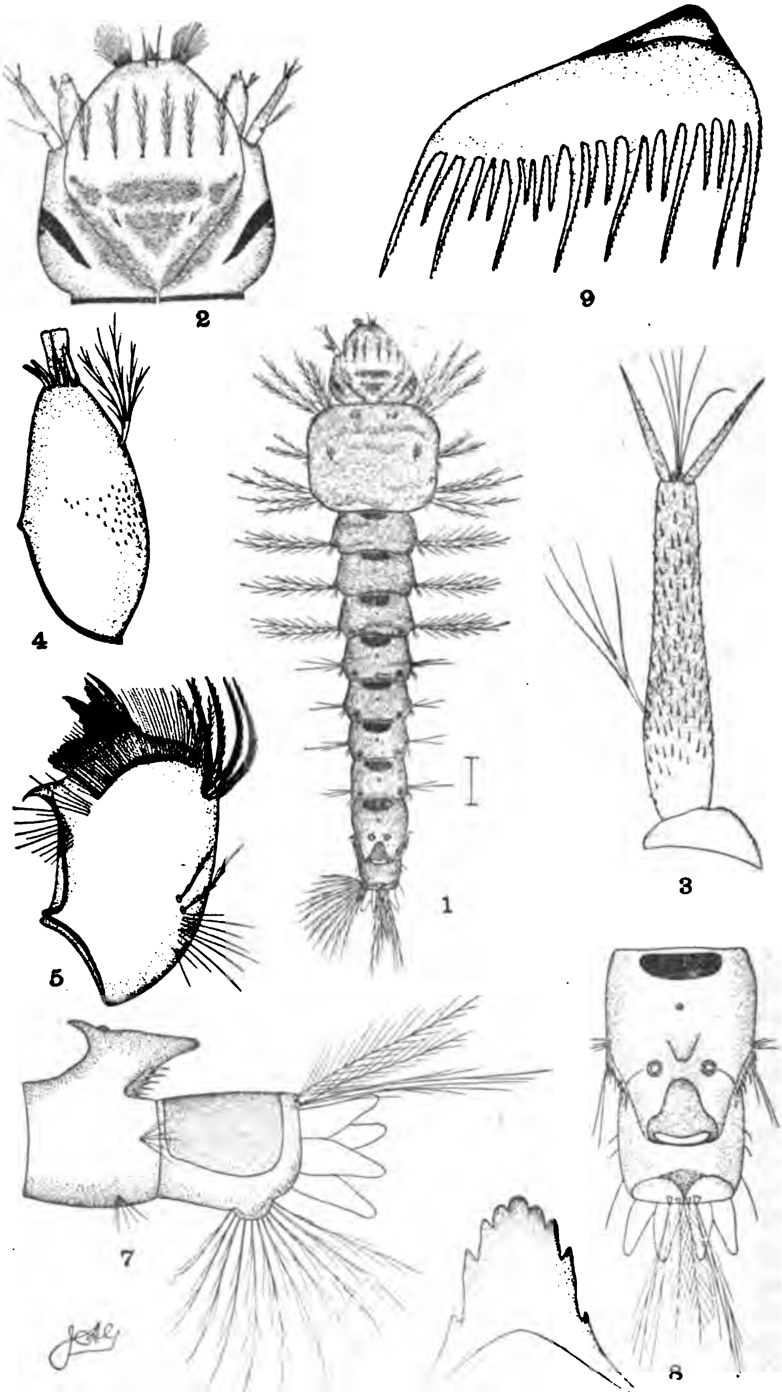

Figure 49.

Anopheles crucians: 1, larva; 2, head from above; 3, antenna; 4, palpus; 5, mandible; 6, mentum; 7, anal segments from side; 8, anal segments from above, showing spiracles; 9, one of the scales: all greatly enlarged. (Original.)

ninth segment is rather stout, dorsal tufts and ventral fan as in others, and with the dorsal plate a little larger. The tracheal gills are short and stout, less than half the length of the other two species.

PSOROPHORA CILIATA, FABR.

The Fringe-legged Mosquito.

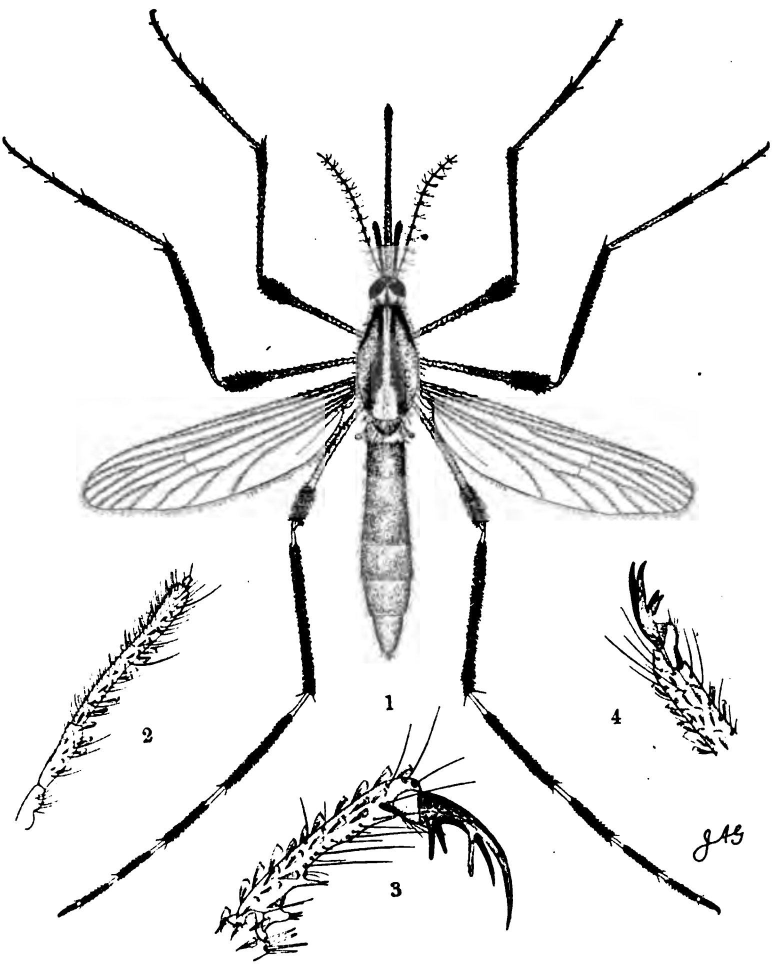

Figure 50.

Psorphora ciliata: 1, female adult; 2, the palpus; 3, anterior, and 4, posterior claws of male: enlarged. (Original.)

This is by far the largest of our mosquitoes and is brownish black in color; the legs are clothed with erect black scales and

the tarsi are banded at the base of the joints with pale yellow in the front and mid-legs and with white on the hind legs. The beak is unbanded and the thorax is longitudinally marked with brown and black stripes. The abdomen is unbanded, dark brown, with scattered whitish scales.

Description of the Adult.

This is a very large, robust mosquito and measures 8–10 mm., = .32–.40 of an inch in length, excluding the beak, which is 5 mm. long, or nearly half the length of the body. The head is covered with mixed brown and white scales, the white ones usually predominating and the brown ones collected into three stripes, which extend from the base of the head to the posterior margin of the eyes. The proboscis is testaceous, wholly black at the apex, with scattered black scales at the base, thickest at the basal half and at the extreme apex. The palpi in the female (fig. 50, 2) are about one-third the length of the proboscis, four jointed, the apical joint minute and variable in size and shape; testaceous with numerous scattered black scales. The male palpi are very large, longer than the proboscis by the last two joints, shaped as in *Culex*, the two terminal joints and the apex of the basal one being dilated; blackish brown in color, testaceous at the base. The antennæ are brown in the female, fuscous in the male, the two basal joints of the former yellowish.

The dorsum of the thorax has a median line of golden brown scales extending its entire length, and on either side of the basal fourth it is edged with a patch of white scales; this median ornamentation is bordered by a lustrous, nude portion which becomes wide posteriorly. The sides of the mesonotum are covered with mixed white and yellowish brown scales. The pleura are brownish, with scattered grayish scales. The legs are pale testaceous, the femora of all with a few dark scales and dense tufts of black scales near the apex. The tibiæ of the anterior legs have many black scales, especially at the apex, while those of the mid and posterior legs are thickly covered with long erect black scales, except at the base. The first tarsal joint of the anterior and middle leg is pale testaceous, with black scales at the apex; the second joint of the anterior and the second and third joints of the middle pair with basal bands of yellowish, the remainder black. The posterior tarsi are covered with erect black scales, with the base of the joints white banded. The claws of the male anterior and mid tarsal joints (fig. 50, 3) are long and unequal, the larger with a median and basal tooth, the smaller with a

single tooth near the base; one specimen examined showed two teeth on this small claw, side by side. The posterior claws (fig. 50, 4) and all those of the female are stout, equal and with a single median tooth to each.

The abdomen is dark brown above and beneath, with whitish scales irregularly scattered over the whole surface, more so ventrally. The dorsal surface appears to have a light-colored central stripe, as the light happens to strike it.

Habits of the Adult.

This is the largest of our New Jersey mosquitoes and its bite is in proportion to its size; but it does not seem to be so poisonous as that of the smaller species. Clothing is little protection when it really wishes to bite, for it gets through coat, vest and two shirts to the skin without any trouble whatever. It seems, however, that it prefers horses to humans and it certainly never attacks in swarms. It is not averse to getting indoors if it can do so without much effort, and it is not infrequently sent in with house captures. In flight it is somewhat slow and heavy, and I doubt whether it ever gets very far away from the place where it bred.

The method of hibernation is not definitely known, but is probably in the egg stage. Adults have never been taken very early in the season, and it is not until June that the species attracts attention in any stage. It continues, however, through September and to the early days of October, so far as our records go.

It is distributed throughout the State, but is usually rare. Only on occasions when a brood has just emerged is it possible to find them in numbers. A few are taken in New Brunswick every summer. Mr. Grossbeck found the species commonly at Spring Lake, near Trenton, July 2d; a single specimen occurred at Hackensack, August 8th; one at Jamesburg, August 16th; two examples at Livingston Park, August 27th, and that concludes the slip record of captures. A few examples only are taken during the summer at Lahaway in spite of the close search made by Mr. Brakeley, and, on the whole, unless one goes into the haunts of this species in the woodlands, it can scarcely be called really troublesome.

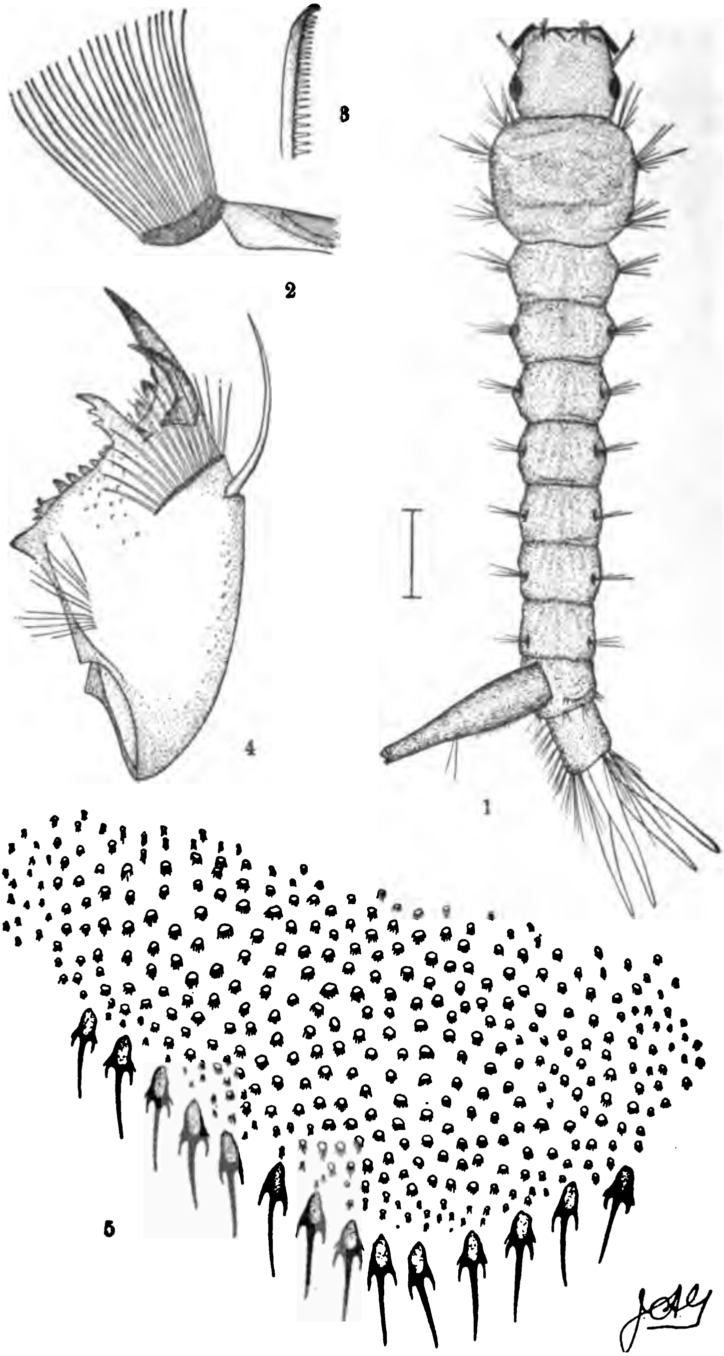

Figure 51.

Psorphora ciliata: 1, larva; 2. one of the mouth brushes; 3. a pectinated hair from the brush; 4. mandible; 5. the scale patch of 8th segment: all enlarged. (Original.)

Description of the Larva.

The larva and details are illustrated on figs. 51 and 52. The full-grown wriggler averages 10 to 12 mm.,=.40 to .44 of an inch in length, though specimens occasionally attain the immense length of 15 mm.,=.60 of an inch exclusive of the anal siphon. They are usually pale gray in color but sometimes dark gray. The head is quadrate, widest at the eyes, slightly excavated on the anterior margin, pale brown in color, and more or less blotched with dark brown spots, though often uniformly colored. Two small hair tufts of four or five hairs are on the vertex, near the anterior margin. The antenna (fig. 52, 10) is yellowish, moderately long and slender, but thick near the base; the extreme apex has two short spines and a small joint, and on a slight offset near the apex are two other spines, one very long and one short. A few large, stout spines are on the basal half, and a slender one, representing the tuft, issues from the shaft one-fourth the length of the antenna from the apex. The eyes are small and occupy the part where the head is widest. The mouth brushes (fig. 51, 21) are small, brown in color and close tightly at the sides of the head when not in use. They are composed of stout hairs, comb-toothed at the apical half, and figure 51, 3, shows one of these hairs greatly enlarged. The mentum (fig. 52, 7) is short and very broad, with seven to nine teeth on each side of the apex; the apical tooth large, as are the two next to the basal, the terminal and basal teeth smaller and uniform. The mandible (fig. 51, 4) is triangular in form, the longest side rounded; the teeth very large and there is but a single dorsal spine. The maxillary palpus (fig. 51, 4) is chunky, the surface covered with short hairs and spines, the apex with short, thick spines, the basal joint small and somewhat retracted. The epipharynx and hypopharynx are shown from above and below at figures 52, 2, 6, 8 and 9.

The thorax is almost as long as broad, not angular, and with three groups of short hair tufts issuing from each lateral margin.

The abdominal segments from one to seven are very stout and robust, with short tufts of hair set in small depressions at the sides, each tuft of from three to five hairs, the larger number in the anterior segments. The eighth segment has the lateral patches of scales (figure 51, 5) consisting each of a large patch of minute scales edged at the anterior margin with a single row of from ten to sixteen large scales, the individual scale with a long, stout apical spine and one or two smaller ones at the sides.

The anal siphon is large, thickest near the base, narrowing considerably apically and is about four times as long as its greatest width. There are from twenty to thirty spines in each of the lateral rows, the single spines very long and slender (fig. 52, 5), with one or two teeth at the extreme base. The ninth segment is slightly longer than broad, with a very short double dorsal tuft and ventral brush, the latter not issuing from a barred area and the tufts extending the whole length of the ventral border. The tracheal gills are long, about three and one-half to four times the length of the ninth segment.

Habits of the Early Stages.

The eggs of this species are laid at the edge of a pool or, perhaps more usually, in a moist depression, where they remain dormant until they become water covered. They are of considerable size, coarsely sculptured and hatch within a few hours after the pools become water filled. Eggs have been obtained from females which have been allowed to bite so as to obtain blood food, and the indications are that blood food is essential to the insect for ovarian development. Mr. Winship has sent in eggs and very young larvæ, dipped from a pool at Monmouth Beach. They were, apparently, resting loosely on the layer of bottom mud and rose when the dipping was in progress, so that quite a number were obtained.

Mr. Seal reports the hatching of the eggs very soon after a pool becomes water filled, and the rapid development of the larva. "On one occasion it began to rain on Monday morning and water soon collected in the bed of a dried-up pond. In the deepest place there was a patch of damp mud with a rotten log lying in it. On Tuesday there were thousands of *Culex (sylvestris)* larvæ about one-eighth of an inch long. Pupæ of both forms had developed by Friday, and on Monday all had enlarged."

The larvæ are immense for wrigglers and are at once recognizable by their size. Unlike others of this series they are predatory and feed on other mosquito larvæ; if there are not enough of other kinds present they turn cannibals and eat each other until some are full grown and complete their transformations. Their appetite is enormous and they feed continuously. Small larvæ are swallowed entire; the larger are seized just below the anal siphon or breathing tube to choke them, and when the struggles cease are devoured to the head. The larvæ are, therefore, scattered as compared with those of other mosquitoes. Mr. Seal makes it as about one to one thousand of *Culex* when both occur

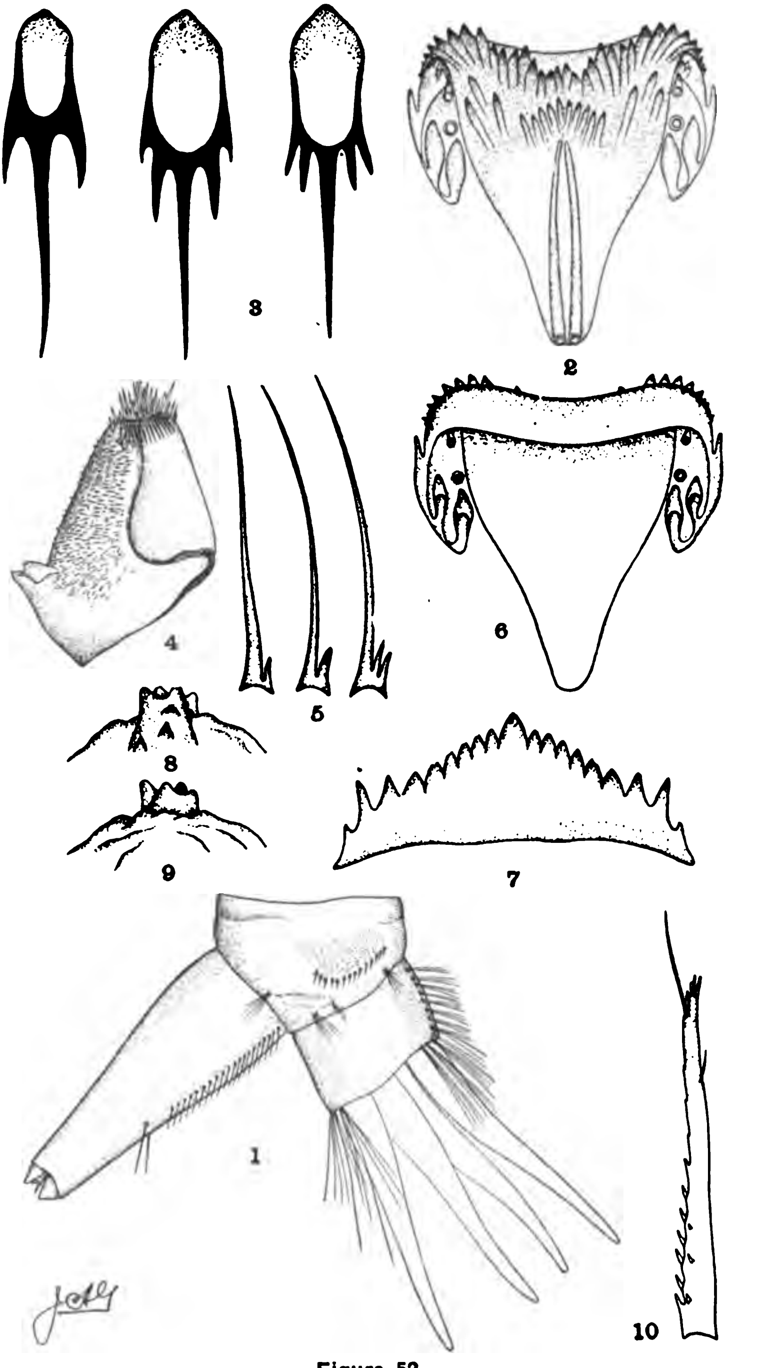

Figure 52.

Psorophora ciliata larva: 1, terminal segments and siphon; 2, epipharynx from above; 6, from below; 3, individual scales showing variation; 4, maxillary palpus; 5, siphonal spines; 7, mentum; 8, 9, hypopharynx from above and beneath; 10, antenna: all much enlarged. (Original.)

together, but that of course is subject to any amount of variation under varying conditions. Mr. Brehme has found pools swarming with small *Culex sylvestris* and a goodly population of *Psorophora* among them. A few days later only *Psorophora* remained and these were scattered and difficult to find. There is no greater enemy of or more effective check to, other mosquito larvæ, than *Psorophora,* and its rank as a pest is not sufficiently high to counter-balance the benefits received from it. Unfortunately it has its limitations. It occurs only in temporary pools or in pools which have been dried out prevously to kill off all fish and similar enemies, and its habits of attacking and devouring its own kind whenever opportunity offers, prevents anything like a great increase in its numbers.

As a rule, perhaps, woodland pools or those at the borders of woodland are favored as breeding places, but I have found and received larvæ from more open pools, even from entirely unsheltered holes near the banks of the Raritan River, so that it can scarcely be said that this is a real woodland mosquito.

Mr. Brehme found full grown larvæ and pupæ on Bloomfield Avenue, Newark, June 25, and in the same place as late as September 25, though at the latter date there were no pupæ, only full grown larvæ. July 20, Mr. Grossbeck collected a few specimens among a lot of Culices in a pool near Paterson. Two days later only the *Psorophora* remained. July 24, Mr. Seal sent in some larvæ from Delair, associated with *Culex confinis.* On the 28th Mr. Grossbeck found them with *sylvestris* at Little Ferry and August 10 there were a few taken by him at Cherry Hill. Aside from these records, there is scarcely a county in the State from which the early stages have not been sent in.

JANTHINOSOMA MUSICA, SAY.

The Big Wood Mosquito.

A rather large or medium sized mosquito, black with deep purple reflections. The beak and legs are black, the hind legs heavily scaled and the last two tarsal joints and part of the preceding one white. The thorax with pale yellowish scales scattered over a black background and the abdomen unbanded. A very characteristic mosquito, recognized at a glance by the metallic purple reflections and the white hind feet.

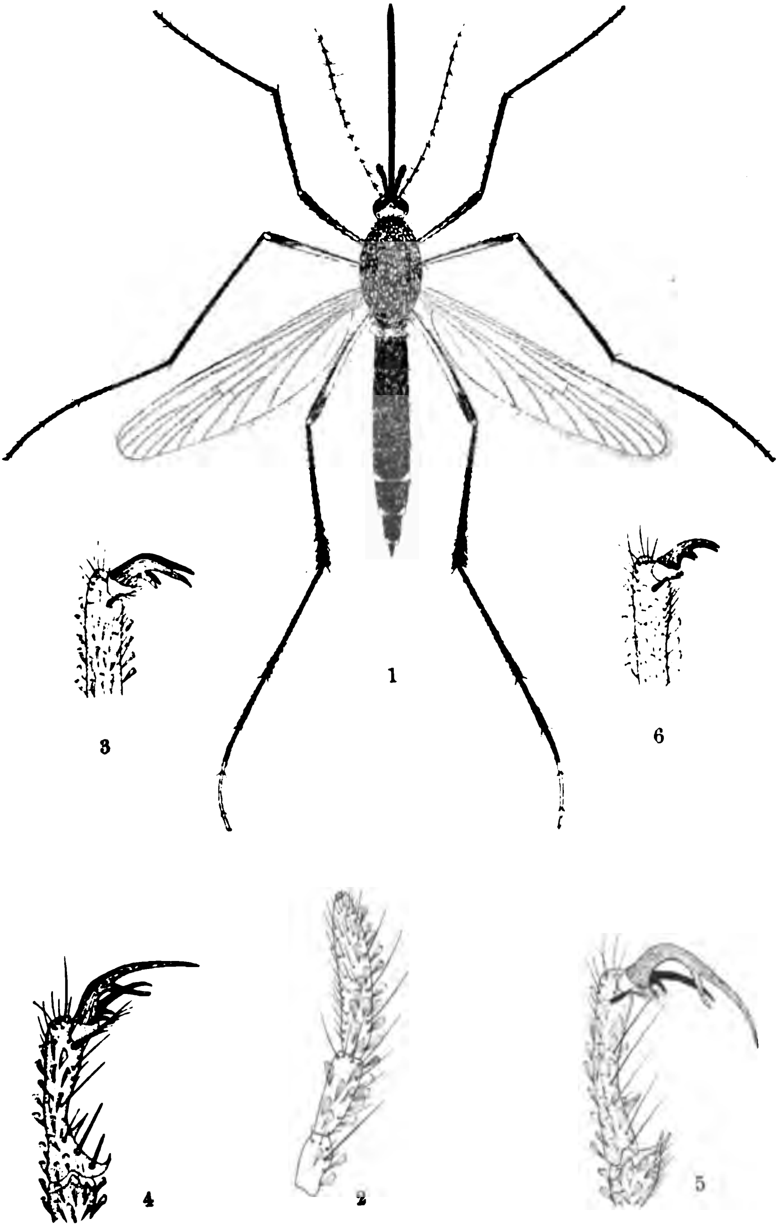

Figure 53.

Janthinosoma musica: 1, female adult; 2, the palpus; 3, anterior claw of female; 4, same of male; 5, middle, and 6, posterior claw of male: all enlarged. (Original.)

Description of the Adult.

This mosquito measures 5 to 6 mm.,=.20 to .24 of an inch in length exclusive of the beak, which is about half the length of the body. The occiput is densely covered with yellowish brown scales; the proboscis is black, without bands; the palpi in the female (fig. 53, 2) are purplish black, rather slender, four jointed, the terminal joint minute and circular. In the male the palpi (fig. 41, 10) are very long, three jointed, longer than the proboscis by the two terminal joints; evenly dilated from the tip of the basal joint to the apex; purplish in color, with a white band in the middle of the basal joint, nearer the base; the apical two joints set with rather short hairs. The antennæ are dark brown in both sexes, the basal joint of the female yellowish.

The thorax is brownish black, profusely sprinkled with creamy yellow scales and the pleura are dark brown with a large irregular patch of grayish white scales. The femora are largely yellowish, black toward the apices on the upper side, and with a white dot at the knee. The tibiæ and the tarsal joints are black with purple reflections, those of the hind legs densely scaled, the tibiæ swollen at the apex, and the whole of the last two tarsal joints and the apex of the middle joint white. The claws of the male anterior and middle tarsal joints (fig. 53, 4 and 5) are unequal, the larger with a curved, blunt median tooth and an acute basal tooth, the smaller with a single tooth near the base, the posterior claws (fig. 53, 6) equal, each with a single median tooth. The female claws are equal on all feet, the anterior and middle ones (fig. 53, 3) slightly sinuous, with a median tooth nearer the base, the posterior like those of the male.

The abdomen is deep metallic purple above, yellowish beneath, the yellow extending up the sides at the apex of the segments, showing slightly on the dorsal surface at the apical angles in the last two or three segments.

Habits of the Adult.

One of the habits of the adult female Mr. Grossbeck describes as follows:

The persistence of this mosquito is almost incredible. On invading its haunts, at first not a specimen may be seen; but in a few minutes it seems as though every individual in the locality has concentrated on one's person. Brushing them away is a mere waste of time for they return to the attack with double fury, and their bite is very painful. So eager are they to insert their

lancets that they can be very readily taken with vials and in one hour I took one hundred specimens in this way. Working pools for larvæ, with both hands occupied, in a locality where they are present, is most unbearable, for with the hands wet their reluctance to leave is still greater and they may be crushed by simply laying the finger upon them. At one time a mosquito rested upon the back of my hand and before she got a hold I disturbed her by sliding my finger towards her; she rose hastily about four inches and immediately descended on the same spot; nine times was this repeated, the insect each time rising four or five inches and alighting within half an inch of the same spot; the tenth time she moved about two inches and I let her get a good bite, then disturbed her in the same way. As fast as I could remove my finger she was back again and only lost heart at the nineteenth time when she flew on my clothing and was bottled. This was repeated many times with other individuals but the experiment was not carried so far.

The testimony of the other collectors is to the same point and there is no doubt that this species shares with *Culex aurifer* the first rank for persistence in the mosquito tribe. Though the experiments made by Mr. Grossbeck and Mr. Brakeley were similar in character they were made without concert or knowledge of the other's work.

The species is not an early one and the first out-door captures were made at Spring Lake, near Trenton, June 30, by Mr. Grossbeck. July 17 and 23 specimens occurred in small numbers on the College Farm near New Brunswick and on the 28th and 29th they were found in the woods at Livingston Park, near the same city. July 28th they were also found in a woodland swamp at Little Ferry, in Bergen County. August 8th, specimens were captured at Hackensack, and on the College Farm. Throughout August the species was found at the various places already mentioned and Mr. Grossbeck had his experience in the Great Piece Meadows about the middle of this month. At the latter locality specimens were obtained, flying, as late as September 9th. The species seems to confine itself to wooded areas exclusively and to prefer those which are low, swampy and cold. It is a matter of some interest that in no stage has the insect been found as yet below the red shale belt. None of the collections made indicate that it is at any time a house mosquito.

As to the matter of hibernation nothing is really known so far as I am aware. It is altogether probable that the winter is passed in the egg stage and altogether possible that the egg may become dry at times; but none of the other species known to me

as egg hibernates make so late a start in the spring as this species seems to do.

The egg-laying habits have been observed by Dr. J. W. Dupree, of Baton Rouge, La., and recorded by Prof. H. A. Morgan. A female specimen captured April 30th, was permitted by Dr. Dupree to feed upon his hand until fully engorged. On the morning of May 1, forty eggs were found, some at the bottom of the glass containing the water, while others were resting upon some fibers of cotton which had accidentally fallen into the vessel. Dr. Dupree thinks it altogether likely that the eggs, which are deposited singly, under normal conditions rest upon floating debris.

Description of the Larva.

The larva and details are illustrated on figure 54. The full grown wriggler measures 7 to 8 mm.,=.28 to .32 of an inch in length exclusive of the anal siphon, and the body is slate gray to blackish in color. Young and half grown specimens are whitish to pale gray. The head is large, slightly smaller than the thorax, widest at the eyes, a little excavated immediately before the antennæ and rounded in front; it is pale yellow and usually immaculate, though at times there are faint clouds, or a distinct brown spot in the center of the vertex. Four hair tufts of two hairs each, in pairs widely apart, arise from the central part of the vertex and a larger one of five or six hairs is at the base of each antenna. The antenna (fig. 2) is very long and slender, sharply curved a little below the middle and tapered evenly toward the apex; in color it is whitish at the base, becoming brown apically; the surface is thickly set with broad spines of which the bases are prolonged, giving the antenna a scaled appearance; the tuft is situated on the curve at the middle and consists of six or eight hairs; the apex has three long spines, one very short one and a small joint. The rotary mouth brushes (fig. 6) are large, wholly composed of simple hair. The mentum (fig. 4) is broadly triangular with a large apical tooth and thirteen to fifteen small ones on each side. The maxillary palpus (fig. 3) is normal with a short, stout basal joint and the mandible (fig. 5) is peculiar by a deep indentation on the dorsal surface, the reduction in size of one of the curved dorsal spines and by having a row of papillæ instead of spines between the large dorsal spines and the teeth.

The thorax is broader than long with the lateral hair tufts short and wholly destitute of tufts on the anterior margin.

The first three abdominal segments are transversely oblong, the remainder subquadrate, each with two hairs to the lateral

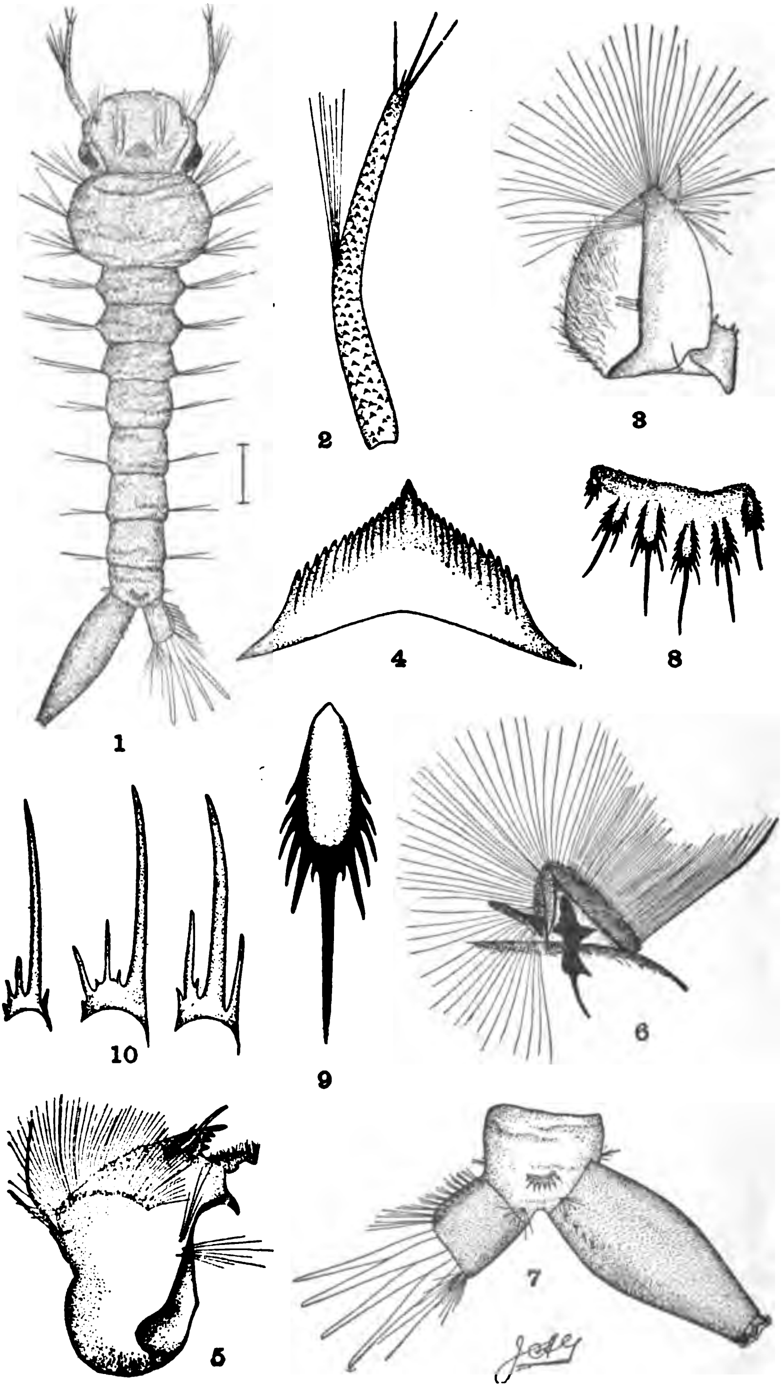

Figure 54.

Janthinosoma musica: 1, larva, 2, its antenna; 3, the maxillary palpus; 4, mentum; 5, mandible; 6, maxillary brush; 7, anal siphon; 8, the band of scales; 9, an individual scale; 10, siphonal spines: all much enlarged. (Original.)

tuft except in the three anterior segments; these with three or more. The eighth segment bears the lateral combs; the scales composing them each with a long apical spine and short lateral ones (fig. 9), attached to a separate band, fringe-like, six or eight scales on each band, the central ones large and long, the lateral ones small and broad (fig. 8). The anal siphon (fig. 7) is very large, greatly dilated in the center and tapering rather acutely toward the apex; each of the lateral pectens have three or four spines, the single spine (fig. 10) slender, with a broad base and a number of long and short upright basal teeth, which may be on one or both sides of the main spine. In small larvæ the siphon is proportionately much larger and is paler in color. The ninth segment is almost twice as broad as long, completely ringed by the chitinized saddle and the fourteen or fifteen short tufts of the ventral brush are confined exclusively to the ventral margin, each issuing from a distinct pit, rather than a barred area which is present as a mere rudiment at the apex. The double dorsal tuft is very small and the anal gills long and slender, a little over twice the length of the anal segment.

Habits of the Early Stages.

"The eggs," according to Prof. Morgan, "resemble somewhat in shape those of *Stegomyia fasciata,* though larger. Short spines pointing toward the so-called head of the egg are uniformly distributed over the entire shell. The egg has a flat and a convex surface, and with the latter uppermost presents a distinctly fusiform shape. Unless debris or a strong film floats upon the surface of the water, all the eggs sink to the bottom of the vessel, which accounts, no doubt, for the irregular periods of incubation. Of the forty eggs deposited during the night of April 30th, a few hatched on May 15th, others hatched May 30th, and still others of the same brood on June 10th. It will be seen from this that a wide range obtains as to the period of incubation.

"The larvæ are active at the surface of the water for the first twenty-four hours, after which they move to the bottom when disturbed, and can remain there as long as forty-seven minutes without coming to the surface for air.

"The larvæ are not 'wrigglers' in the true sense of the term. They jerk characteristically when suddenly disturbed, but ordinarily move from the top to the bottom of the vessel at an angle of about 45 degrees, with little motion save the rapid movement of the oral cilia. The passing of the larvæ from the top to the bottom of the water with apparently little effort gives them a

graceful appearance. While at the bottom of the glass they catch large bundles of Spirogyra, which are broken into smaller pieces as the surface is approached."

The earliest larva taken in New Jersey was by Mr. Brehme, at Hemlock Falls, June 20th. Mr. Grossbeck found it next, in a large woodland pool with partly rocky bottom, on the Garret Mountain, near Paterson. June 30th Mr. Brehme sent in larvæ taken from the South Orange Mountain, from which adults were obtained July 2d and 3d. July 15th larvæ occurred on the College Farm and near the old copper mines at Arlington. August 8th there was another brood on at the College Farm, and on the 15th others were taken at Livingston Park. During this month Mr. Grossbeck found the adults in the Great Piece Meadow, and during September he found large numbers of larvæ in the woodland pools there and in the Troy Meadows. As late as September 30th he collected the larvæ in numbers, full grown and ready for the change. Pupation began October 1st, and the first adult occurred October 4th. Development during the summer is very rapid; but in late fall it becomes much slower.

Altogether, while this species is sometimes common and bites hard, it can scarcely be considered a pestiferous species, because it does not leave the woods and breeds only in such swampy areas as are not often visited.

CULEX JAMAICENSIS, THEOB.

The Spotted Legged Mosquito.

A dark slate colored or black mosquito of large size. The femora and tibiæ are spotted with yellow and the tarsi are white banded at their bases. The beak has a white central band, and the wings are thickly scaled with black and white scales, giving them a dotted appearance under a lens. The abdomen is black with incomplete basal bands and C shaped marks.

Description of the Adult.

This is a large mosquito, 6.5–7 mm., or a little over a quarter of an inch in length; the beak is about 2 mm., or slightly less than one-third the length of the body. The head is blackish, with cinereous scales more or less scattered over the surface and forming a narrow border to the posterior part of the eyes; the proboscis is black at the apical third, yellowish centrally, gradually merging into a black base. The palpi in the female are black-

ish, white at the apex of the third joint, the fourth joint usually very small, with a few bristles at the apex. In some specimens this joint is rather large, oblong, with an obtuse apex. The male palpus is black, only slightly dilated, the basal joint has a whitish band in the center and is almost as long as the proboscis; the terminal joint is a little shorter than the central one and both have a narrow pale band at the base. The antena of the female

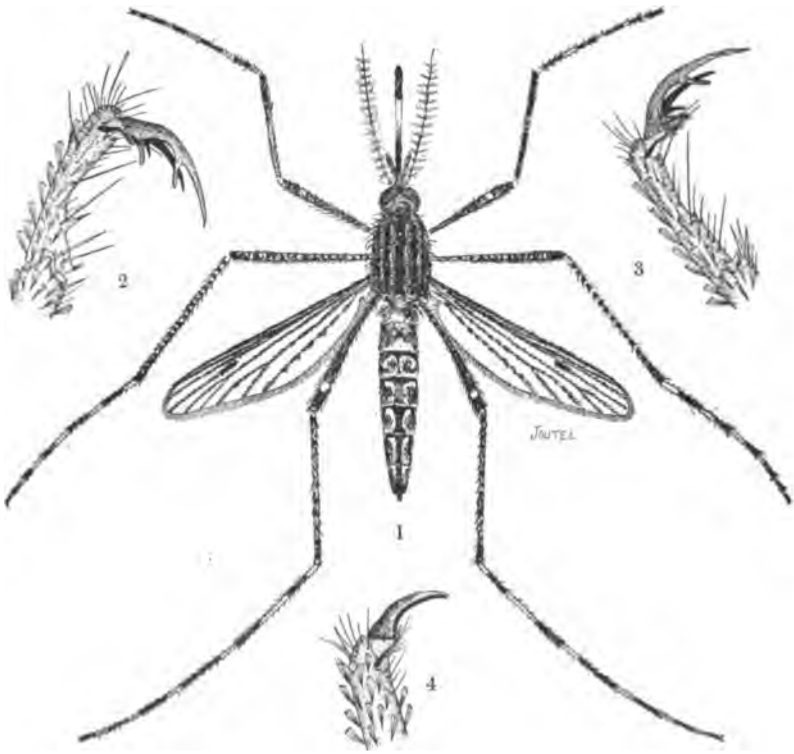

Figure 55.

Culex jamaicensis: 1, female adult; 2, anterior; 3, middle, and 4, posterior claws of male: all enlarged. (Original.)

is brown, with the basal joint yellowish brown; in the male it is brown with paler plumes.

The thorax is black, and has generally a striped appearance, as shown in the figure; absolutely fresh specimens, however, pinned without handling, and before they have had opportunity to denude themselves in the breeding jar do not show the stripes. It is evenly covered with black spiny clothing and has cinerous scales, diffused over the posterior part and collected into two or four

spots in the anterior portion. The pleura are black with small patches of grayish scales. The femora are black with scattered yellow scales; the apex is white and there is a broad white band near the apex on the posterior femora, a narrower band on the anterior, and almost none on the median pair. Beneath they are wholly yellowish. The tibiæ are black with a white dot at the base and many white scales collected into spots on one side. The tarsi are black with broad white rings at the base of all joints except the fifth on the fore and mid feet. The first tarsal joint has, in addition, a broad white band in the center, less distinct on the mid and anterior pairs. The claws of the fore and mid tarsal joints of the male are unequal in length, the larger with a median and basal tooth, the smaller with a basal tooth only. The posterior claws are equal and simple as are all those of the female. The wings are hyaline with the veins clothed with mixed black and white scales; at the base of radio 4 + 5 a small portion has no white scales, making a distinct black spot.

The abdomen is jet black, the first segment with a patch of yellowish white scales in the center of the apical margin; the second banded with the scales prolonged forward in the middle; the following segments with two C-shaped marks, back to back, but divided by the black. These marks are sometimes diffused or become less curved posteriorly, until the apical segments have two longitudinal marks. Beneath it is brownish or slate colored.

Habits of the Adult.

Though this is scarcely to be considered a rare mosquito, it seems to be very local, and as an adult does not seem to get away from the immediate vicinity of its breeding pools. It has never been sent in by any of my correspondents and none of the collectors have taken it in the collections made to determine what species were flying. Although a lively breeding place is only a few hundred feet from my house, the species has never made its appearance on my porch. Adults could be collected easily enough in the immediate vicinity of the pools, but none were seen only a few feet away.

The female has fully developed mouth structures and may bite, though she is not aggressive. Mr. Grossbeck reports being bitten by one specimen, and says that the bite does not hurt at all at the time, but that the swelling and the pain develop soon afterward.

So far, material has been received only from Delair through Mr Seal, and from New Brunswick through office collections. It

is probable that the species occurs under favorable circumstances throughout the State, but both larvæ and adults are so strongly marked that if they were at all common anywhere, examples would almost certainly have reached me. The species winters probably, in the egg stage, and does not become noticeable until mid-summer.

Description of the Larva.

The full grown larva is illustrated fig. 56 and measures 8 to 9 mm., or about one-third of an inch in length, exclusive of the anal siphon, is very stout in build and of a dirty pale yellow color. Young and half grown larvæ are more slender and whiter except for the food matter in the alimentary canal, which is usually dark. The head is rather long, tapering considerably toward the front, uniformly yellow in color and without maculation. In young larvæ it is dirty gray. In the center of the anterior part of the vertex are found short hair tufts of four or five hairs each and another of the same size is at the base of each antenna. The antenna (fig. 56, 2) is rather short, gently curved, dilated about one-third from the base, then tapering gradually toward the apex; in color it is black, the basal third whitish and the surface with scattered stout spines. The tuft is short, consists of about a dozen hairs and is situated at the center, slightly nearer the base, directly above the dilation. The apex has three moderately long spines, a shorter one and a small joint. The rotary mouth brush (fig. 56, 5) is yellowish brown in color, composed entirely of simple hair. The mandible (fig. 56, 4) is normal in shape, without a row of long spines on the margin between the apex and the two curved, dorsal spines. The maxillary palpus (fig. 56, 3) is short and broad, almost circular in outline, with a moderate apical tuft and a small basal joint. The mentum (fig. 56, 6) is almost as high as it is broad at the base, with only slightly curved sides of from twelve to fourteen small teeth on each side of the apex.

The thorax is almost circular in outline, with a smooth surface save slight depressions on the anterior and posterior parts. The faint lateral angles each give rise to a number of short hair tufts and there are several very small tufts on the anterior margin.

The abdominal segments are very broad in comparison to the thorax, with four or five hairs to each lateral tuft, in the two anterior segments up to seven. These tufts are short in the mature larva, but in the young larvæ they are comparatively much longer and the abdomen is narrower. The eighth segment has

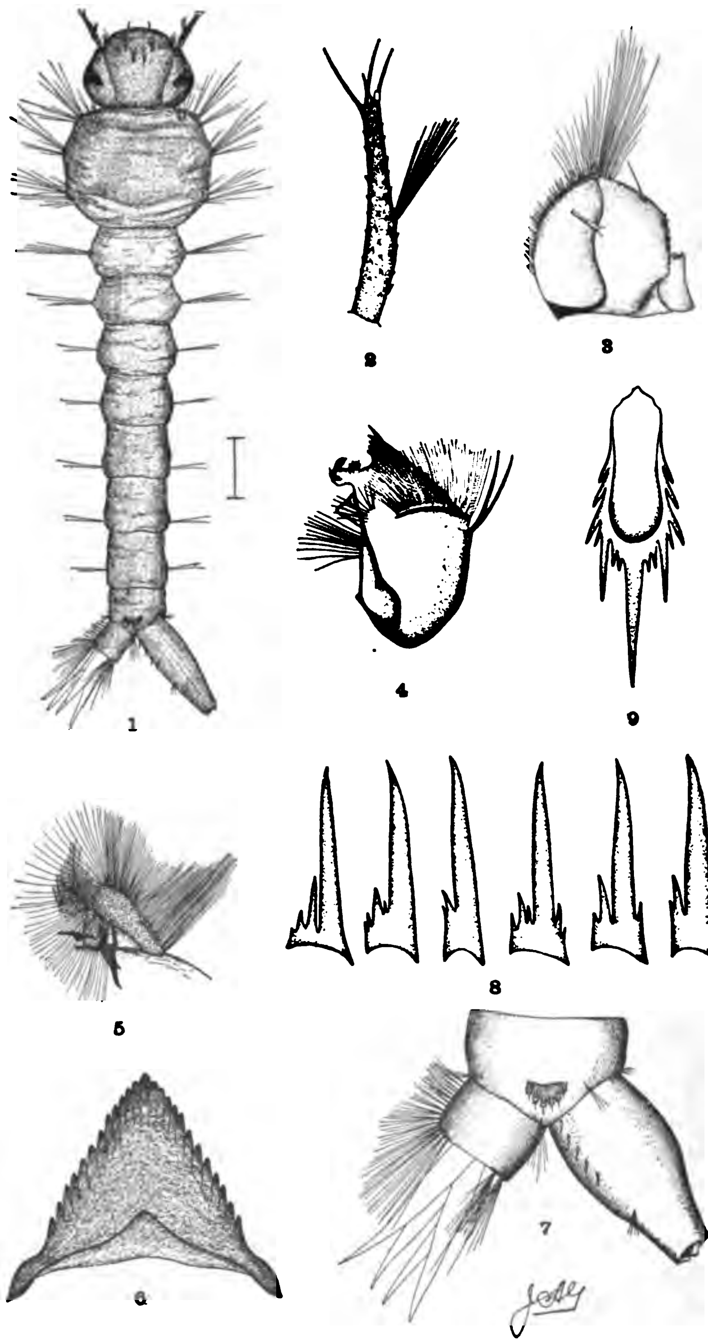

Figure 56.

Culex jamaicensis: 1, larva; 2, its antenna; 3, maxilla; 4, mandible; 5, the mouth brush; 6, mentum; 7, anal segments and siphon; 8, siphonal spines showing variation; 9, a single scale from 8th abdominal segment: all much enlarged. (Original.)

six scales on each side attached to a separate band—fringe-like—in the form of a semicircle. The individual scale (fig. 56, 9) is somewhat variable but always has three large spines, the longest forming the apex; the smaller spines border the sides and there may be one, two, though possibly none between the larger ones. The anal siphon (fig. 56, 7) is yellow, moderate in length, usually stout and broadly dilated near the base, though specimens occur where the dilation is scarcely perceptible. The double row of spines does not extend half the length of the siphon and consists of but three to five spines in each row, with small teeth crowded at the base, often on both sides (fig. 56, 8). In young larvæ the siphon is ringed near the middle, the basal half being whitish and the apical half dark gray. The ninth segment is longer than broad, with a small barred area on the ventral part of the posterior margin from which arise rather short tufts of hair, and smaller tufts on the ventral margin beneath the barred area. The dorsal tufts are short, each with one hair much longer than the rest. The anal gills are long and taper to a fine point with the trachea a mere hair line, to be seen in the living larvæ.

Habits of the Early Stages.

In New Brunswick the only breeding places known are on the College Farm, where, in woodland pools, a few specimens were taken, and two or three small temporary lot pools not far from my house. In the woods the species was associated with *sylvestris, serratus* and *musicus;* in the lot pools with *pipiens* and *restuans*. The lot pools were located by Mr. Dickerson in 1902, and these wrigglers could be found there at almost all times after the last days of July. In 1904 the same pools were collected over July 28th and some thirty full grown larvæ were found associated with thousands of *C. pipiens,* which were collected for experimental purposes. On the 30th, another lot was brought in, mostly in the pupal stage. August 9th, the pools were again loaded with full grown larvæ and pupæ, and as specimens were needed and the pools were small, on the 10th they were collected clean. At that date there were no young larvæ and the effort was to clean out the entire crop. August 17th the pools were again filled by larvæ of all sizes up to the pupal stage, making less than seven days from the hatching of the egg to the pupal stage. The latter stage rarely last over twenty-four hours, so that a brood may come to maturity in a little over one week. August 23d all stages were again found, from young just out of the egg to the pupa.

These pools do not really differ from dozens of others in the city, and even in the vicinity, where the species does not occur. One of them becomes very foul occasionally from a sewage admixture and this seemed in no wise to discompose the insects. The others have the ordinary shale mud bottom with little or no vegetation. The larvæ somewhat resemble those of Psorophora at first sight and, as they always occurred with *pipiens*, it was believed that they might be predatory; but a series of experiments failed to bear out this belief.

Prof. Glenn W. Herrick, of Mississippi, described this larva in 1904 and detailed some of its habits, which it may be interestng to quote: "I first noted the larva in an open sewage drain of the college campus in 1901. They attracted my attention by their large size as compared with the larvæ of *C. fatigans*, which were so numerous in the same drain. At this time several adults were taken from the weeds and grasses overhanging the ditch. * * * In the summer of 1903 I noted scores of large larvæ in a roadside pool near Starkville, Miss. At first sight they appeared to be the larvæ of *Anopheles*, for apparently they were in horizontal positions. Never having seen *Anopheles* larvæ so abundant, it seemed worth while to stop and examine them in some detail. Much to my astonishment these larvæ were found to be members of the genus *Culex*, or at least of some genus closely related to *Culex*. Moreover, the great majority of them were lying apparently horizontal, just below the surface film of water. * * * From this time forth many larvæ of this species were found in other rain-water pools and abundant opportunity was afforded to observe them. With the one exception of those found in the sewage ditch, I have always found these larvæ in transient rain-water pools.

"The larvæ are interesting from the position they assume in the water. When the larva rises to the surface it assumes at first about the same position as the larva of *Culex*. But after a moment, if left undisturbed, the body, with a slight jerk, floats quickly to an approximately horizontal position with the head on a level with the surface of the water, in which position the mouth brushes are able to skim the surface, as it were. The larva can change quickly and easily from the horizontal to the suspended position. The body, instead of lying so nearly horizontal as does that of *Anopheles*, hangs suspended—like a piece of slack rope—between the head and respiratory tube and considerably below the surface of the water. The respiratory tube projects out of the water at least a third of its length and points forward when the larva assumes the horizontal position. * * * The

larvæ are splendid swimmers and are constantly swimming along the surface, but nearly always in a backward direction.

"Mr. Theobald states that the eggs, as noted by Dr. Grabham, are laid singly. Although careful search for the eggs was repeatedly made, they could not be found. The larvæ would invariably appear in a pool within twelve hours after the formation of the pool by a rain storm. The conviction was gradually forced upon me that the eggs were deposited in or upon the mud to await the coming of the rain."

In a general way our observations agree with those of Prof. Herrick; but in New Jersey the habit of assuming the horizontal position seems much less developed. The younger larvæ do assume and for a time maintain it; but when nearly mature the larvæ take the horizontal position upon rising to the surface, maintain it for a few moments only and then drop back to the normal *Culex* position. As to the oviposition, I believe that Prof. Herrick is right: the eggs are laid on the moist mud very close to the edge of a pool or in the bed of an old pool itself, and there they remain until stimulated to development by a water covering.

CULEX DISCOLOR, COQ.

The Mottled Mosquito.

This is a yellowish brown mosquito of rather small size, with legs and beak banded; the abdomen is mottled with brown and yellowish white, and the wings are spotted. It is the only New Jersey species in which this combination occurs and is, therefore, very easily recognized.

Description of the Adult.

This mosquito is of medium or small size and not very robust in appearance. In length it is 4 to 6 mm.,=.16 to .24 of an inch excluding the beak. The latter is short and thick, excavated centrally and about one-third the length of the body, the apical third black, central portion white, gradually merging into the black at the base. Sometimes the white extends almost to the head. Across the wings it averages in measure about 9 mm., or .36 of an inch. The eyes meet on the top of the head and occupy the whole anterior part. The occiput is covered with yellowish scales. The palpi in the female (fig. 57, 2) are four-jointed, rather broad, the terminal segment reduced to an extremely small

circular knob, and set with hairs which are not as long as is usual. The palpi in the male (fig. 41, 3) are three-jointed, the basal joint only slightly longer than the two terminal ones together; the fan-like tufts toward the tip brownish black in color. The antenna of the male is plumose, color brown, with the usual cup-shaped segments and circle of fine hair. In the female the antenna is shorter than the beak and composed of twelve short segments.

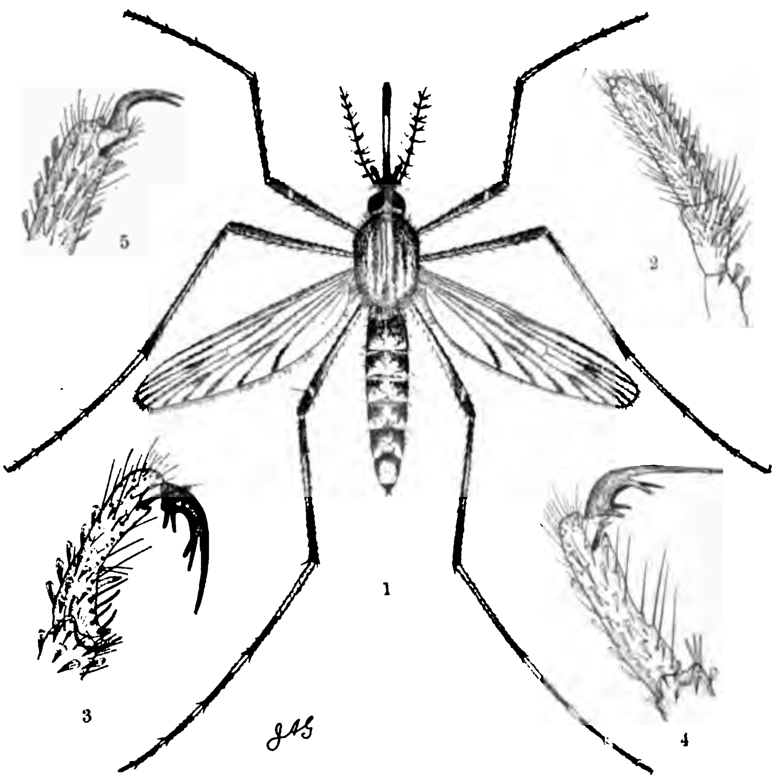

Figure 57.

Culex discolor: 1, female adult; 2, its palpus; 3, anterior; 4, median and 5, posterior claws of the male: all enlarged. (Original.)

The thorax is dark brown with the dorsum irregularly striped with yellow scales. The femora with mixed black and yellow scales above, wholly yellow beneath, the anterior and posterior ones with a pale oblique band near the apex, almost obsolete in some specimens; mid femora usually without a band and when present very inconspicuous. The posterior part of the anterior

and mid tibiæ, and the anterior part of the hind tibiæ almost wholly with yellow scales. The first tarsal joint with many yellow scales to about one-third from the apex, then wholly black; remaining tarsal joints white banded basally, becoming narrower toward the apex, the last one often entirely black.

The claws of the male are alike in the anterior and mid tarsal joints, each having one long claw with a median and basal tooth and a shorter one with a single tooth near the base. The longest claw of the mid tarsal joint is not curved as much as in the anterior one. The posterior claws are small, simple, of equal length and very much curved toward the base. The claws of the female are alike on all feet, being the same as the posterior ones of the male.

The wings are hyaline, with the scales on the veins collected into white and black portions as follows: costa, black centrally; sub-costa, black, the outer two-thirds divided twice with a white portion; radius 1, basal half white, the black beginning before the fork with radius 2, and extending to wing margin; radius 2, black at basal third, also black at fork with radius 3; radius 3, black at basal and apical third; radius 4 and 5, black at apical two-thirds; media 1 and 2, black, beginning a short distance from base and extending to cross vein, black again a little on each side of fork with media 3, and again at margin; media 3, black at both ends; cubitus 1, black, beginning a short distance from base and extending to fork with cubitus 2, white for a short distance, then black to cross vein, and again at the margin; cubitus 2, slightly black at tip and anal vein black at apical fourth. The black at the forks, radius 2 and radius 3, and media 1 and 2 and media 3 are so close together that they appear as distinct spots; others are not so obvious.

The abdomen is apically banded with yellowish white, the bands prolonged forward in the middle and intersected irregularly with the dark brown of the basal part; in some specimens this intersection is carried further, so that the brown predominates, giving the abdomen a mottled appearance. Sometimes the brown is carried across the base of the segment almost dividing the band in two. Beneath it is whitish in the most central part which merges into the brown of the sides.

We know nothing of the habits of this mosquito nor whether it bites. The adult has never been taken by any of the collectors, and from the practical standpoint it need not be considered at all, in New Jersey.

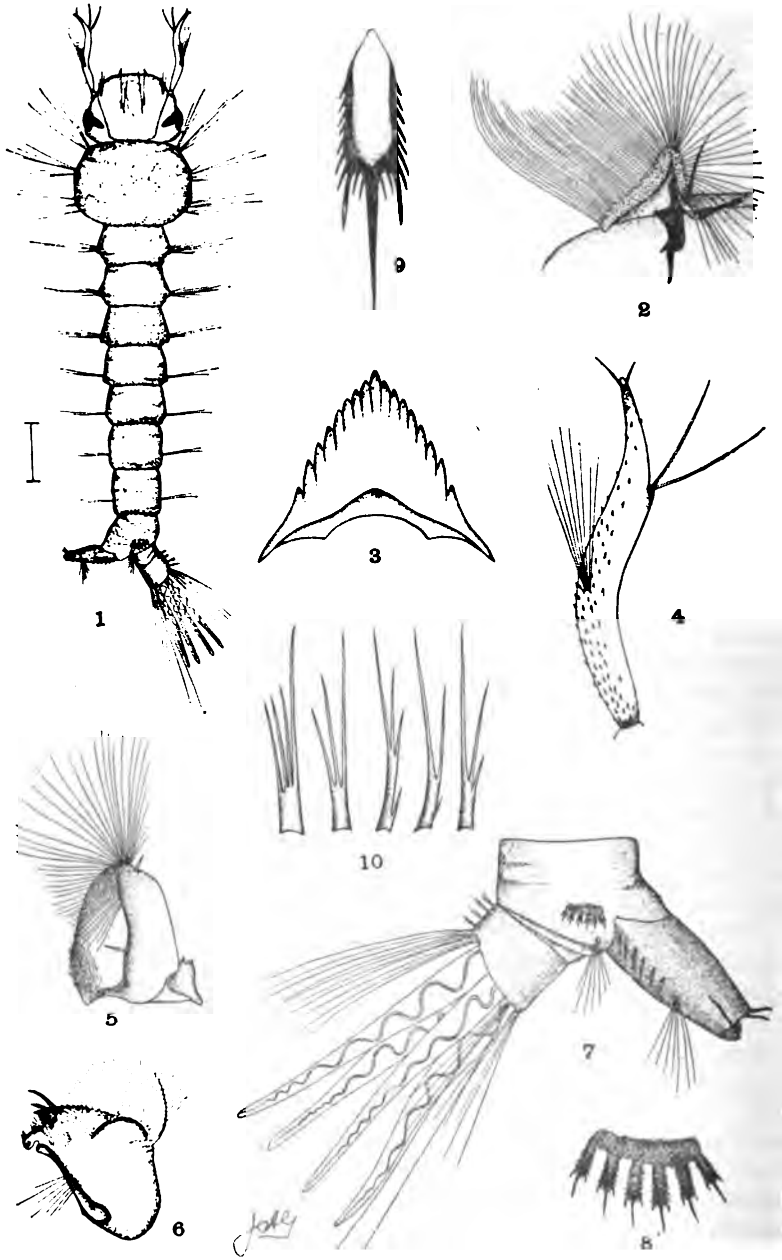

Figure 58.

Culex discolor: 1, larva; 2, one of the mouth brushes; 3, the mentum; 4, antenna; 5, maxillary palpus; 6, mandible; 7, anal segments, siphon and tracheal gills; 8, a scale band of the 8th segment; 9, an individual scale: all much enlarged. (Original.)

Description of the Larva.

The larva which is shown on figure 58 is yellowish brown in color when full grown. It measures from 7 to 8 mm.,=.28 to .32 of an inch in length including the anal siphon, and is rather short and stout. The head is almost as large as the thorax, one and one-half times as broad as long, excavated immediately before the antenna and square in front; it is pale yellow, without markings of any kind, and from the center of the vertex arise four hairs, each from a separate pit, and a tuft of four or five hairs at the base of each antenna. The antenna is large and white, partly covered with small stout spines, almost as long as the head is broad, thickest centrally, and with an out and an incurve, terminating almost to a point. The tuft is well below the middle and consists of about a dozen hairs. The two long spines, midway between the tuft and the apex, represent two of the four spines which usually crown the apex; the apex with two short articulated spines and a small joint. The eyes occupy the sides of the head and are crescent-shaped, with a small detached portion at its posterior margin. The hairs composing the rotary mouth brushes (fig. 2) are simple. The mentum (fig. 3) is triangular, broader than long and is very constant in form, with eight teeth on each side of the apex.

The mandible (fig. 6) is of the usual form, but is peculiar by possessing only a single dorsal spine. The maxillary palpus (fig. 5) is scantily clothed with hair, while the apical tuft is rather large and of long hair. The basal joint is small with a number of very small spines at its apex.

The thorax is wider than long, with rounded margins and moderately long hair tufts. When the larva is about to change into the pupal condition, the thorax becomes shriveled, the dorsal surface depressed and large prominences form on the anterior margin, giving the impression of an entirely different species.

The abdominal segments 1 to 3 have lateral tufts of hair, each with four to six hairs, while segments 4 to 7 have only two hairs to each tuft. The eighth segment is prolonged upward on the dorsal part to receive the odd shaped base of the siphon. The lateral combs consist of from five to eight scales, arranged in the form of an arc on a separate band, fringe-like, as shown in figure 8. The individual scale is oblong, with three stout spines directed downward, the central one very much longer than the other two, and the sides also fringed with spines (fig. 9). The anal siphon is very small, three times as long as broad in its greatest length and with two small, curved spines at the apex;

the siphonal tuft is exceptionally large and consists of from six to eight hairs. There are from 5 to 8 spines in each lateral row, all with two or three long teeth (fig. 10). The ninth segment is transversely oblong, widest at the dorsal part, and with the usual double tuft of hairs. The barred area of the ventral part is small and has only three or four tufts of long hair and a row of very short tufts. The anal gills are long, twice as long as the siphon, and provided with obvious tracheæ.

Habits of the Larva.

This larva has been sent in only by Mr. William P. Seal, of Delair, N. J., in small numbers. The first lot was collected June 18, 1903, received at the laboratory June 20th. They were at once recognized as new to us, attracting attention first by their unusually prominent, white antennæ; second, by the very long anal gills; third, by the habit of resting on the bottom, back down, antennæ pointing upward and mouth brushes kept in constant motion. Pupæ were formed June 23d and 24th, and on the 27th and 28th adults emerged—a pupal period of four days. A second lot was received July 24th, but they were small, did not do well and only one female adult was secured August 8th. Mr. Seal states that the larvæ are rare, and he noted their habit of remaining below the surface and feeding at or near the bottom.

This species is so far removed in general character of both larva and adult from the other species of *Culex* that it should not really remain associated with them. The bottom feeding habits of the larvæ are further characteristic and far removed from those of the more typical species.

CULEX SOLLICITANS, WALK.

The White-banded Salt Marsh Mosquito.

The distinctive characters of this species are the broadly white banded tarsi, the white banded beak and the yellowish white bands at the base of the abdominal segments, crossed longitudinally in the center by a broad continuous line of the same color. The thorax is golden brown with the sides silvery white. This combination of characters occurs in no other New Jersey species and renders it recognizable at a glance.

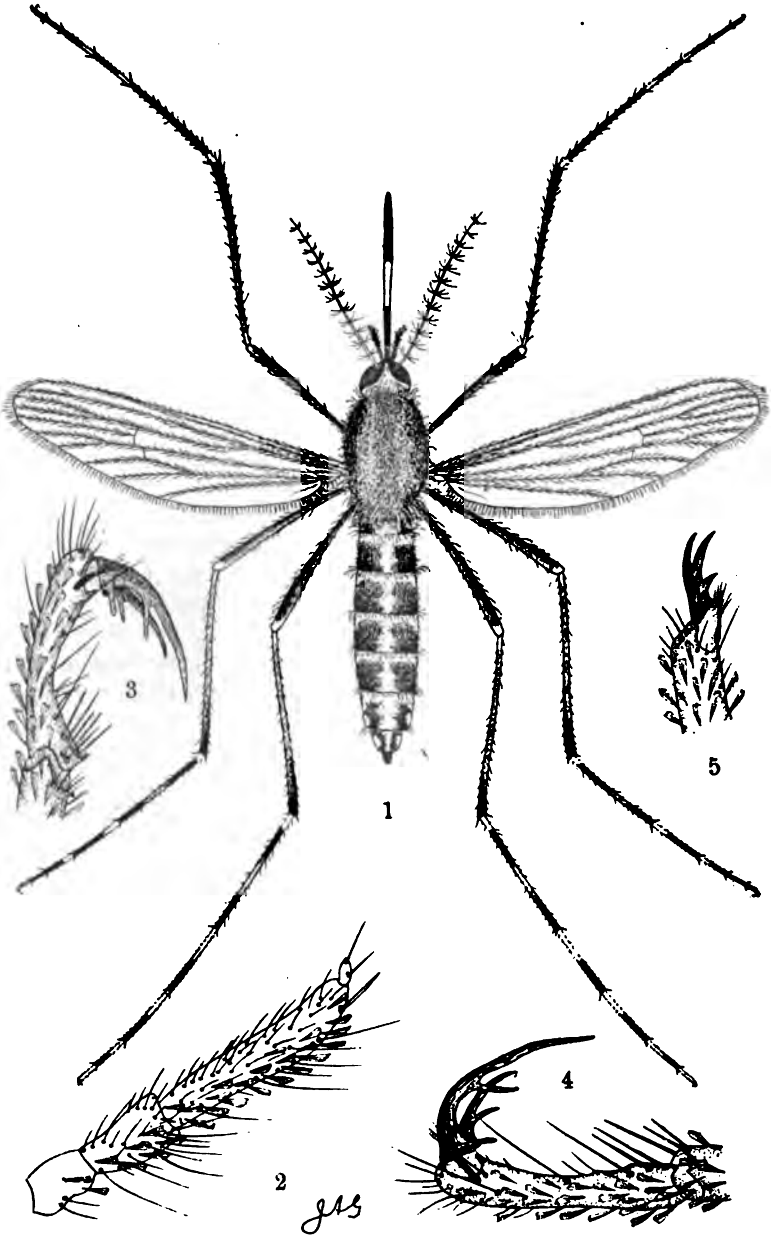

Figure 59.

Culex sollicitans: 1, adult; 2, the palpus; 3, anterior; 4, median and 5, porterior claws of the male: much enlarged. (Original.)

Description of the Adult.

This is a medium sized or rather large mosquito of a beautiful brown color. The body, exclusive of the beak, is about 5.5–6 mm.,=.22–.24 of an inch in length; the beak less than half its length, or averaging 2.5 mm. The head is dark brown at base the scales of the outer edges gradually mixing with the yellowish ones toward the central part, which become bright creamy yellow between the anterior part of the eyes; there is also a narrow yellow border on the posterior margin of the eyes. The proboscis is black, with a well defined white central band. The palpi in the female (fig. 59, 2) are blackish brown and thickly scaled; the apical joint elliptical, pointed at the apex, usually with one or two bristles, though it may not have any. In the male the palpi resemble those of *cantator* in shape, but are somewhat shorter and stouter, extending beyond the tip of the proboscis: the two apical joints are narrowly white banded at their bases and there is a broader yellowish band in the center of the basal joint; the fan-like tufts pale yellowish brown in color. The female antenna is dark brown, while that of the male is brown with pale brown plumes.

The clothing on the dorsum of the thorax is spiny, deep brown in color, with numerous golden yellow scales often forming two diffuse longitudinal rows; the lateral margins blackish brown, deeply in contrast with the silvery white pleura. The femora and tibiæ are ochraceous, with many black scales sprinkled over the surface; the knee spots are yellowish without scales and the apices of the tibiæ are black. The tarsi in the hind legs are black, broadly white banded at the bases of the three intermediate joints; the fifth joint wholly white, while the first is narrowly white banded at the base and with a distinct ochraceous median band. The fore and mid tarsi are similar, except that the bands are dirty white in color, proportionately narrower, disappearing altogether on the fourth joint; the ochraceous band on the first tarsal joint less distinct and the fifth joint with some dark colored scales. In the male the claws of the anterior and mid tarsal joints (figs. 59, 3 and 4) are unequal, the longer with a median and basal tooth, the shorter with a median tooth slightly nearer the base. The posterior claws (fig. 59, 9) are small and equal, with a single tooth on each. Those of the female are alike on all feet, being the same as the posterior claws of the male.

The abdomen is dark brown, with rather broad yellowish bands at the base of the segments, becoming slightly wider laterally; a longitudinal stripe the entire length of the abdomen

crosses the bands in the center, dividing the body color into blocks. On the two apical segments are white spots laterally, near the base. The bands and stripe are generally well defined, but specimens are common where they are very much diffused, the apical segments being entirely yellow and the blocks appearing as irregular spots. Beneath it is dirty yellow or grayish.

Habits of the Adult.

As this is perhaps the most common mosquito in New Jersey in ordinary seasons, and is certainly the one that holds down property values along shore, it deserves fuller treatment than any other of the species, and it has been and will be, as a matter of fact, frequently referred to in the preceding and following parts of this report. *Sollicitans* in New Jersey breeds only on the salt marshes, and some marshes or sections of marshes breed them in such numbers that it is a bold man that would agree to stand quietly for any considerable period of time. Records are not wanting of persons driven almost frantic by them, and sensational stories are sometimes set afloat that individuals have been made unconscious or delirious from their bites. *Sollicitans* bites not only hard but readily, without much preliminary singing, and bites as readily during the day as during the evening. Ordinarily the specimens hide in the grass or in the shelter of low bushes during the day and do not voluntarily rise if undisturbed; but at the slightest disturbance they investigate, and in a moment a cloud surrounds the disturber. No one who has not met with *sollicitans* on its native heath can have any idea of what a swarm really means. I am tolerably well seasoned myself and have been with collectors and fishermen who claimed to be practically mosquito proof, but we were on one occasion simply driven out of a woodland at the edge of a marsh along Seven-Mile Beach. But not only in their breeding area are they so troublesome: miles inland I have battled with them on cranberry bogs while studying the pests of that crop, and have been glad to get away, wringing wet with perspiration, smarting with bites on every exposed part of the body and on some parts that became so closely covered when stooping that the insects struck blood through the clothing.

When the wind blows hard enough to make flight difficult during the day, the insects crawl up the legs of the victims, probing until they find a place to attack. On the male adult such places are not readily reached unless low shoes are worn, but a woman cannot stand it long, and children with exposed legs or

covered by thin stockings only often suffer frightfully. I have seen little ones with their legs covered with bites, swollen and sometimes bleeding; really ill and crying from pain.

It is this species that, in conjunction with *cantator,* makes screened porches necessary and the burning of Chinese punk and other repellants at night desirable. It is no exaggeration to say that half the pleasure derivable in the resorts along the New Jersey Coast is lost because of the annoyance caused by this insect. It has one good point, however; it does not make any special effort to get indoors. At New Brunswick, where my house is fairly well screened, *sollicitans* does not get in more than once or twice during the summer, while *C. pipiens* and *Anopheles punctipennis* work their way in despite screens. Even along shore the indoor mosquitoes are nearly always *pipiens,* though *sollicitans* may be plentiful outside. Mr. Brakeley, whose place at Lahaway is in the midst of the area of *sollicitans* invasion, usually sits in his study in the evening with windows on both sides open and unscreened. Yet *sollicitans* rarely comes in, though *perturbans* and even *cantator* come in freely and bite readily.

The subject of mosquito migration has been already dealt with, and in this connection it is only necessary to say here that a large proportion of all the female specimens that mature on the marsh leave it soon after they are fully developed and fly inland—a longer or shorter distance, as conditions may determine. All these migrants are sterile, and no matter how small the brood on the marsh, some of them always fly from it. From these breeding places the species covers the entire Cape May peninsula—practically the entire pine area—extends up the Delaware nearly to Philadelphia; indeed, it does reach the Philadelphia Neck in some seasons and in general reaches inland a distance from twenty to forty miles. Assisted by *cantator,* it dominates the territory to the top of the first ridge of the Orange or Watchung mountains, and sometimes extends beyond to the second ridge. From the Newark meadows it extends north to Paterson and covers all the intermediate territory. It does not in this territory quite equal *cantator* in number and distribution.

Mr. Brakeley, at my request, kept records of the dates at which the insects first appeared at Lahaway, and in 1903 one example was taken on each of May 27th and 29th. In 1904 single individuals were taken May 23d and 24th. The latest recorded date was October 8th, 1903, when a specimen was taken attempting to bite. On the marshes the species appears late in April, or early in May, and usually lasts until late October.

I have seen both sexes of this species feeding in the blossoms of wild cherry, and it is quite probable that vegetable juices form a considerable element in the food of this species. As to the number of broods, that depends altogether upon weather and tide conditions, from five to eight being, perhaps, usual.

The egg-laying habits of the species are interesting and were carefully studied.

EGG-LAYING HABITS.

When it became evident that this species did not behave as, according to published records, it should, and that neither eggs nor larvæ could be obtained at New Brunswick, though the adults simply swarmed there, I arranged with the Keystone Rod and Gun Club, at Anglesea, for the use of part of their land for a series of experiments meant to determine just where and how eggs were laid. Every facility was afforded by the club and by its members individually, and during the early summer of 1902 Mr. Dickerson and myself planted a series of eight tubs, which were meant to represent various marsh conditions, and stocked these with larvæ, pupae and adults, covering with netting to control the outcome, but leaving two open to the swarms infesting the surrounding meadow. We found gravid females abundant in certain places and confined a number of them in quart jars under varying conditions. Some jars had water and some had none; some had vegetation, others only bare marsh mud, and so altogether about a dozen jars were prepared, each to receive from two to ten gravid females. Next morning a large proportion of the jars had eggs, all of them black and laid under so many conditions that conclusions were difficult. Another series of captures, when carefully examined, led us to believe that the eggs became black within the ovary of the female, and that they were of that color when laid.

The tub experiments, details of which need not be given, indicated that the marsh mud was the place to look for the eggs of *sollicitans*, and some pieces of sod from an old breeding area were at once secured. The result was that in twelve hours we had a large brood of baby wrigglers and had demonstrated, by actual observation, that the marsh mud everywhere round about was more or less densely covered with mosquito eggs; most densely in the lowest, damp areas. Other observations made during the year confirmed this conclusion, and a series of laboratory experiments with sods brought to New Brunswick showed that the eggs might survive an almost complete drying

out; not for a day or a week, but for months; hatching promptly as soon as they became water covered.

Nevertheless, though it was now possible to appreciate the conditions under which the species became at times so horribly abundant, there were several points of practical interest that were left undetermined. For this reason, in 1903, I assigned Mr. Viereck to the Cape May station, where opportunities for study were abundant, and the following series of experiments brings out in relief those peculiarities that were only guessed at before.

MR. VIERECK'S EXPERIMENTS.

July 24th, placed one dozen gravid females into each one of two quart jars, in which the bottom was thinly covered with marsh sod. July 25th, some were dead, and only three females had the abdomen yet distended. July 27th, only three living specimens remained and in these the abdomen was collapsed. July 28th, all were dead. July 30th, the sod was examined and black eggs were found, most of which must have been laid during the night of July 24th. "The eggs were evidently white when laid and became black subsequently." It rained during the night of July 29th, and water covered the bottom of one of the jars in which baby wrigglers were found on the 30th. These lived until August 5th, when only a few survived. On the 6th, a new lot of babies hatched and some sound eggs yet remained in the sod. Only a few eggs in this series collapsed.

August 2d, prepared two one-quart jars with moist lint at the bottom and two others with lint covered with moist marsh mud, which had been sterilized to make certain no live eggs were introduced. Ten gravid females were placed in each and oviposition began while the jars were yet under observation. One specimen extended its ovipositor, darted its end into the sod until it found a suitable place, then laid six eggs, one after the other, and flew off. Another placed fifty-two eggs, one by one, in an irregular row about an inch long, in one continuous laying. A third took great pains hunting up a suitable place by darting its ovipositor in many directions before placing each egg. At 6 P. M., and a few minutes after, an injured female laid all its eggs in a heap, one by one, but rapidly. At 7.30 P. M., those first laid were black, the rest assuming a gray color and becoming black from the end first laid to the end last to appear. Some of the eggs were placed and kept in a dark place, but these blackened as rapidly as did those kept in the light. Eggs taken from the

ovary of a female ready to lay, perfect in size and form, failed to darken in color, and collapsed.

August 3d, eggs of this second series were placed in four jars and covered with seawater 100 per cent., seawater 50 per cent., seawater 25 per cent., and pure artesian spring water. No larvæ had hatched in any of these jars August 6th, after being covered for seventy-two hours, and the water was then poured off, leaving only a little moisture. August 10th, again covered the eggs in the fresh-water jar with water of the same kind and wrigglers hatched at once. The same experience resulted with the other jars, tending to show that the eggs must be at least partially exposed before they hatch. Eggs of this series that had been kept nearly dry since they were laid, were covered with water at 3.35 P. M., August 8th, and at 4.08 P. M., wrigglers had begun to emerge. August 13th tested jar 4 in which the sod was completely dry and found the eggs hatching after one and one-half hours. August 15th, poured water over the entire sod and wrigglers began to appear in three minutes! Adults from this lot were obtained August 24th. September 23d, some eggs of this series that had been kept in a damp closet since laid, were covered with water and hatched within an hour afterward.

August 4th, the third series of experiments was started and a dozen jars were stocked, each with ten gravid females. In the jars which contained only dry lint no eggs had been laid up to August 6th, when the jars were brought indoors. August 8th, the eggs in the jars in which the lint had been allowed to get perfectly dry after the insects had oviposited, were found collapsed. At noon, August 8th, put water into jars 7 and 8, and at 3 P. M. wrigglers were present. These jars were put out in the marsh August 12th, and some ditch water was added. August 15th, put the young larvæ into a small artificial pond and recovered the sod with marsh water. On the 19th, there was another lot of young larvæ in the jars, while those in the small pond were approaching pupation. August 11th, added water to another jar of this series and on the 12th, larvæ were found. On the 25th, there was a fresh hatching from this series, and this left some eggs still in good condition.

The fourth series was started August 14th, twelve or more gravid specimens being confined in each of twelve jars containing as follows: No. 1, dry sand; No. 2, wet sand; No. 3, dry lint; No. 4, wet lint; Nos. 5 to 12 inclusive, ordinary upland soil over moist lint. Not all the specimens had laid eggs on the 15th, and some were yet alive on the 19th. In jar 4 the lint was so saturated that the water just failed of flowing it and here the

insects were tempted to lay eggs on the sides of the jar an inch above the wet bottom. August 19th, the eggs in jar No. 8, were covered with water, but no larvæ hatched from this series. Some of the eggs in jar 4, became covered with water September 1st. and hatched. September 5th, another lot was covered and also hatched. Some of the eggs were covered with water soon after they were laid and were kept covered until September 5th when, no larvæ having hatched, the water was poured off and they were allowed to dry. September 23d, when these eggs were again covered with water they hatched freely. Eggs that had been kept dry since laid were covered with water September 5th, and hatched. Eggs kept under similar conditions, one series on marsh mud, the other on upland soil, were covered with water September 30th. Five hours later wrigglers were found over the marsh mud; but three days later none had yet appeared over the upland soil!

In one case a number of gravid females were caught in a net with a mass of other material. This was all placed in a jar and the mosquitoes began ovipositing at once, in masses. Only a few of the eggs had turned black twenty-four hours later when they were covered with water. A small number of these black eggs hatched; all of the white examples collapsed.

Some other experiments were made and from those as well as from the above record, Mr. Viereck concludes as follows: "No black eggs were laid and only one specimen was found with black eggs in it. All eggs laid outdoors (presumably) and in the experiment jars (certainly) were white when laid. They changed from white to steel color and then to black, gradually, in one hour and a half. Eggs were laid on moist material, but not into water nor on dry sand or lint. Some hatched over night when the fresh eggs were covered after having turned black; but usually they did not hatch until two or three days had intervened before they were covered with water. One lot placed under water did not hatch in weeks; these eggs when dried and again covered with water, did hatch. In one jar several hatchings took place at intervals of three days. Eggs kept indoors and exposed to the air of the room collapsed. Eggs under the influence of the moisture of a closet did not collapse when in the mold of black grass marsh, but did collapse when the material was ordinary garden soil or lint. Eggs hatched in all percentages of sea water, their further progress depending on food. Larvæ died in water at 40 degrees C. (103° Fahr.); they survived at 37 degrees C. (98° Fahr.)." Mr. Viereck is further of the opinion that "whether the eggs will collapse or not after being laid, depends also on the stage of de-

velopment when they are laid: thus, those fully developed remain entire, while those not so mature, as the ones laid by an injured female, need moisture to develop them further."

The general statement here made is undoubtedly correct, but it should be added that the records indicate that the eggs laid under such stress as Mr. Viereck indicates are not fertilized, and, therefore, not viable in any event. It should be further noted that the apparent difference between Mr. Viereck and myself concerning the color of the eggs when laid, is open to a very simple explanation. When my observations were made there had been a drought of considerable length, and inviting places for oviposition were few and far between. This had delayed the females in their work of providing for a continuation of their kind; yet development of the ova had gone on within the body and a considerable percentage changed color. This, coupled with the fact that only black eggs were found in the marsh mud, justified my belief that the eggs became black before being deposited. Mr. Viereck's conclusions undoubtedly state the rule.

Conclusions from the Observations.

Egg-laying may begin as early as a week after development into the adult condition. This is based upon observations made late in July on specimens of the brood then recently hatched. There are no direct observations as to how long a specimen may live before eggs are laid. We have assumed that all the eggs which a specimen of this species is capable of developing mature at one time and the limit in number observed for one female is close to 200. We have no positive experiments to prove that this is so; but examinations made of females that have oviposited showed a rigid thickened abdominal wall and an entire absence of ovarian structures. There was simply a hollow shell in which only the digestive system remained and the worn looking specimens died readily in confinement. Yet I am assured by Dr. Dupree, of Baton Rouge, Louisiana, that *sollicitans* lays several batches of eggs in that State, and has a much wider range of breeding places than in New Jersey. The statements here made must then be recognized as limited to our own conditions and, so limited. Mr. Viereck's experiments and my observations afford not the slightest evidence that *sollicitans* at any time lays more than one batch of eggs, not much exceeding 200 in any case.

No eggs are laid in water or on its surface; this is an important fact because it eliminates permanent bodies of water as breeders

of this particular species. The eggs must be dry or at least not water covered for at least twenty-four hours after they are laid; otherwise they will not hatch. On the other hand, these eggs may remain dry for three months or longer, without losing vitality, and if at any time after they have been dry for over a week or two they become covered with water, hatching is rather a matter of minutes rather than of hours. I have seen a low meadow covered with an inch of water from a heavy storm, and have found this water swarming with wrigglers a few hours afterward. After two days of sunshine the water had disappeared and with it the millions of larvæ. Slow drainage is a positive advantage in danger areas for it will induce the eggs to hatch on a high tide or heavy storm and will destroy the resulting brood. This is an advantage because it absolutely eliminates just that many possible adults and will come nearer to actual extermination in the long run than any other possible method. Mr. Viereck's experiments also prove, what I suspected as the result of my own observations; that a certain percentage of the eggs laid did not hatch when first covered with water. This is a provision of nature for the continuance of the species; that in case of a covering too slight to bring the brood to maturity, there should be a remnant lying over until a later period, ready to hatch at the second or third covering, or until the spring following. In other words, the evidence tends to show that out of say 200 eggs laid by an individual, 100 would hatch the first time they were covered with water provided the eggs had been uncovered for at least twenty-four hours. Of the remainder, fifty would probably hatch at the second covering and of the balance, ten would lie over until the season following, while the others would hatch if covered during the season. Assuming however that, of the 200 eggs from an individual of the first brood, none were covered by water during the summer for a long enough time to produce the larva, the indications are that at least fifty per cent. would lie over safely until the season following, ready to take advantage of spring conditions. Slow drainage then, that will permit the marshes to be covered for a few hours on extra tides or in heavy storms, is better than a drainage that is more rapid in summer, but apt to be slow enough in spring to mature a brood. Perfect drainage, sufficient for all seasons, is the ideal to be aimed at; but that is sometimes much more expensive than the slow process, which will answer every practical purpose.

As for the points selected for oviposition by the females, that includes practically every damp place on the salt marsh and the country immediately adjacent thereto. For example a cornfield noted by Mr. Viereck came down to a corner edging on the

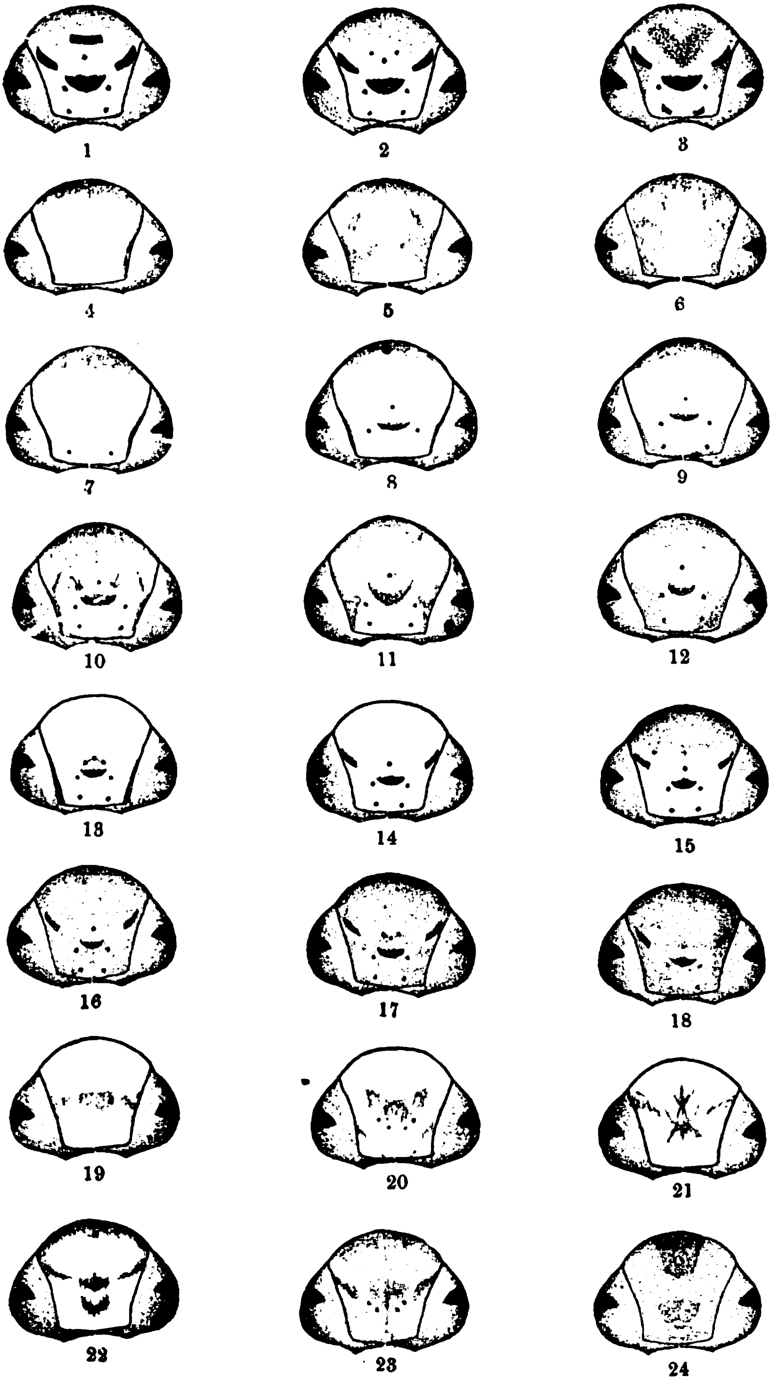

Figure 60.

Head markings of larvæ of *C. cantator*, 1-3; of *C. sollicitans*, 4-6; of *tæniorhynchus*, 7-12; of *C. canadensis*, 13-18; of *C. sylvestris*, 19-24: all very much enlarged. (Original.)

marsh, and while it was plowed and planted like the rest, a pool which formed in that marsh corner contained *sollicitans* larvæ while none were found in apparently much more attractive places away from the direct salt marsh influence. Where a shore town has been laid out with streets and avenues running in all directions through a salt area, the depressions between the streets retain their salt character and will breed *sollicitans* whenever water gathers, though they may be dry from June 1st to December 1st. I have in mind several places of this kind which become water covered in winter only, remain water covered until late in May or early in June and mature a brood composed of practically all the eggs that were laid on that place during the preceding season. There is no water from June 1st or thereabouts until frost; but mosquitoes are always there and eggs are laid freely.

On the other hand, once out of the immediate influence of the marsh, neither eggs nor larvæ are found, no matter how abundant the adults may be. This is a point which I have tested and had tested again and again, every one of my assistants having collected within the range of *sollicitans* from the salt marsh to the inland, and all having had exactly the same results, whether they collected blindly on definite instructions, or intelligently, with a direct knowledge of the point they were detailed to clear up.

Mr. Viereck's collections and notes are especially valuable on this point, for the Cape May Peninsula is comparatively narrow, is thoroughly dominated by *sollicitans* and was explored in almost every section. The net results of Mr. Viereck's collections is exactly that of all others who have done similar work. There is no breeding away from the salt marsh region broadly considered.

It is not necessary that there should be any considerable depth to the mud in which the eggs are laid. I have never found larvæ in pools with a clear sandy bottom; but I have found them in grassy depressions among the sand hills, where there was just a scum of the organic mud deposit on the surface.

Description of the Larva.

The larva and details are illustrated at fig. 61. When full grown, it is from 8–9 mm., or .32–.36 of an inch, in length. It is a large, robust wriggler, dirty gray in color as a rule, but often yellowish white. The head is small in comparison to the body, one and one-half times as broad as long, and yellow in color. The sides and base are shaded with reddish brown and the vertex, though immaculate, generally has lateral blotches and is often clouded in front (see fig. 60, 4, 5 and 6.). A dark clouded

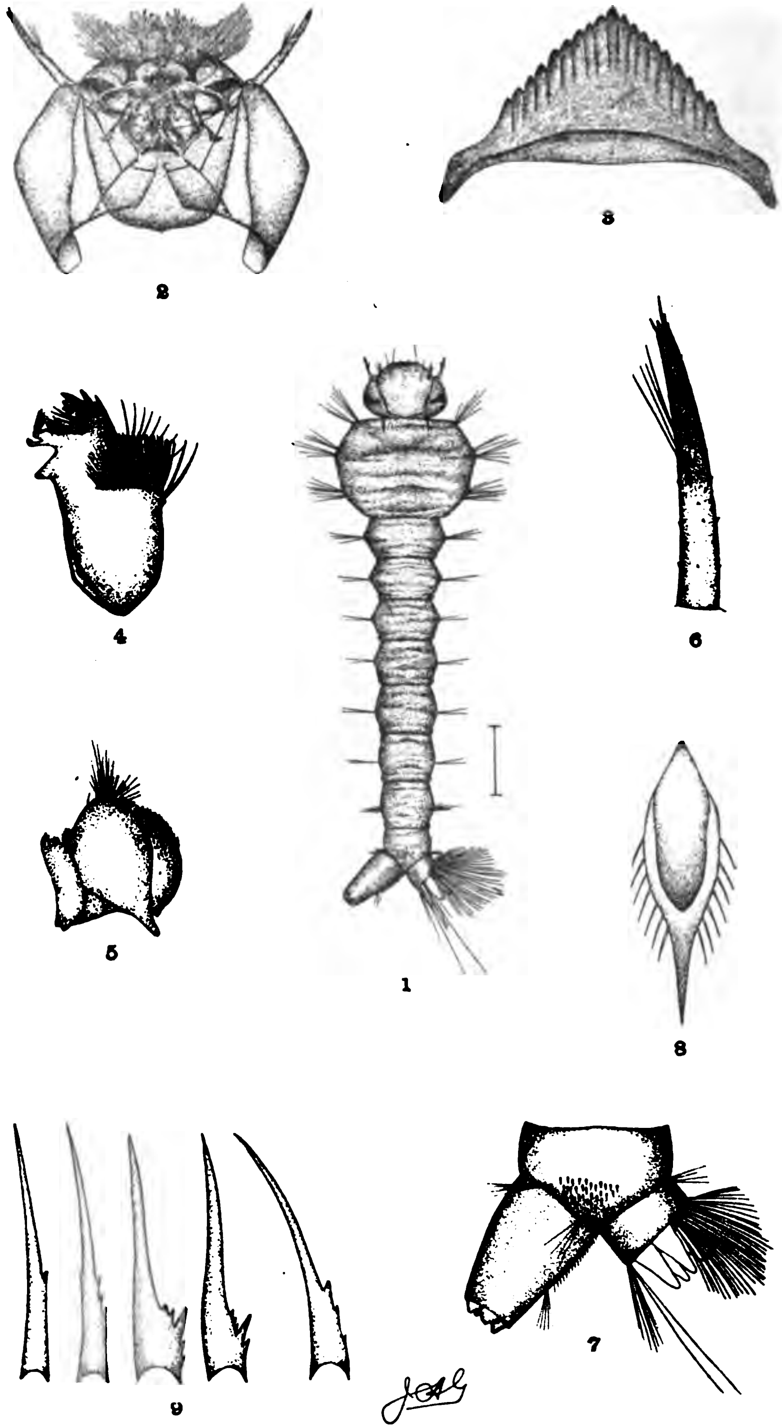

Figure 61.

Culex sollicitans: 1, larva; 2, head; 3, mentum; 4, mandible; 5, maxilla; 6, antenna; 7, anal segments and siphon; 8, a single scale; 9, siphonal spines showing variation: all much enlarged. (Original.)

head, rarely, does occur and is due to the extension of this anterior blotch. Four rather long, single hairs arise from the sides of the vertex in the anterior part, two slightly in advance of the others, and a small tuft of four or five hairs is at the base of each antenna. The antenna is short (fig. 61, 6) and evenly tapered toward the apex; pale yellow at the base, dark brown on the apical half and with small stout spines over the surface. The tuft of four or five hairs issues from the shaft at about the middle, and the apex has a few short bristles besides the small joint. The eyes are large, some being blunt and others acute on the dorsal surface. The rotary mouth brushes (fig. 61, 2) have the more central hairs pectinated. The mentum (fig. 61, 3) is triangular, with eight to twelve teeth on each side of the apex. The mandible (fig. 61, 4) is normal but somewhat elongated, and the maxillary palpus (fig. 61, 5) is short and chunky with a hairy surface, a large basal joint and comparatively a very small apical tuft.

The thorax is large, wider than long, with two transverse depressions on the dorsal surface and a number of smaller wrinkles. The angulations are not very prominent and the hair tufts arising from them very short; there are two other small tufts on the dorsum near the anterior margin.

The abdominal segments are subquadrate in form, the joints more constricted in the anterior segments. The hair tufts are very short, two hairs to the lateral tuft, but more in the first, second and seventh segments. The eighth segment has lateral patches of scales from twenty to forty in number, the single scale (fig. 61, 8) drawn to an acute point at the apex and with small spines fringing the sides. The anal siphon (fig. 61, 7) is short and stubby, about one and one-half or twice as long as broad, with two rows of toothed spines from sixteen to twenty-four in each. The spines have from one to five teeth and may be either slender or stout, as shown in the figures. The ninth segment is small, almost square and completely ringed by the chitinized saddle. The dorsal tufts are normal, while the ventral brush is thick, composed of short hairs, the tufts confined to the barred area. The anal gills are very short, often no longer than wide.

Habits of the Early Stages.

When the eggs become covered with water by rains or by the tides the larvæ develop and emerge, often within a period of minutes rather than hours. They thrive equally well in salt or in fresh water and develop most rapidly where the food supply is

most abundant. I have never found this species breeding elsewhere than on the marsh or at its very borders, in the salt hay zone along shore which cannot exactly be called marsh. It is always a shore or marsh mosquito and every little hole on the marsh may breed it. A week is all that is necessary to bring the larva to maturity, and the pupal stage is short or long, according to temperature.

At Anglesea young larvæ were taken by Mr. Dickerson as early as March 5th, though development at that period is slow. March 12th larvæ were more abundant and evidently developing generally. At that time Mr. Dickerson tested the temperature of the water in which larvæ occurred and found that it ranged from 42 degrees to 50 degrees Fahrenheit. At this temperature microscopic life multiplies slowly and the wriggler food supply is limited; therefore this first brood of larvæ dawdles along for a month before adults are ready to emerge. Breeding continues until early October; but after that few eggs remain to be developed, except for the spring following. If the wriggler succeeds in reaching the pupal stage before a pool dries up it is usually safe, for the pupa will live twenty-four hours in soft mud and develop as an adult; indeed not more than twelve hours is really needed, because I have had mosquitoes emerge within that period. Larvæ more than half grown will survive in soft mud a few hours, and if the pool is then refilled by rain or tide will revive and complete their transformations.

The general character of the breeding places has been already described and need not be more specifically referred to here.

In its actions or method of feeding the larva offers nothing out of the usual course, and it is readily subject to the effect of oils and other coverings. As a rule the water it inhabits is tolerably clean, but it is able to sustain itself in quite foul and fermenting pools.

CULEX PERTURBANS, WLK.

The Irritating Mosquito.

This is another large species, with tarsi broadly white banded at base of joints and a ring of same color in center of first joint. Beak white-ringed in center and abdomen with indistinct, narrow bands of white at base of segments. The general brown color and large size, together with the exceptionally broad bands of the legs, makes it very conspicuous and easily recognizable.

Description of the Adult.

This is a large brown mosquito, measuring from 5.5 to 6.5 mm., = .22 to .26 of an inch in length, exclusive of the beak, which is 2.5 mm. long. The head is brown, with numerous creamy scales over the surface and extending between the eyes, and some black ones in the posterior part directed backwards.

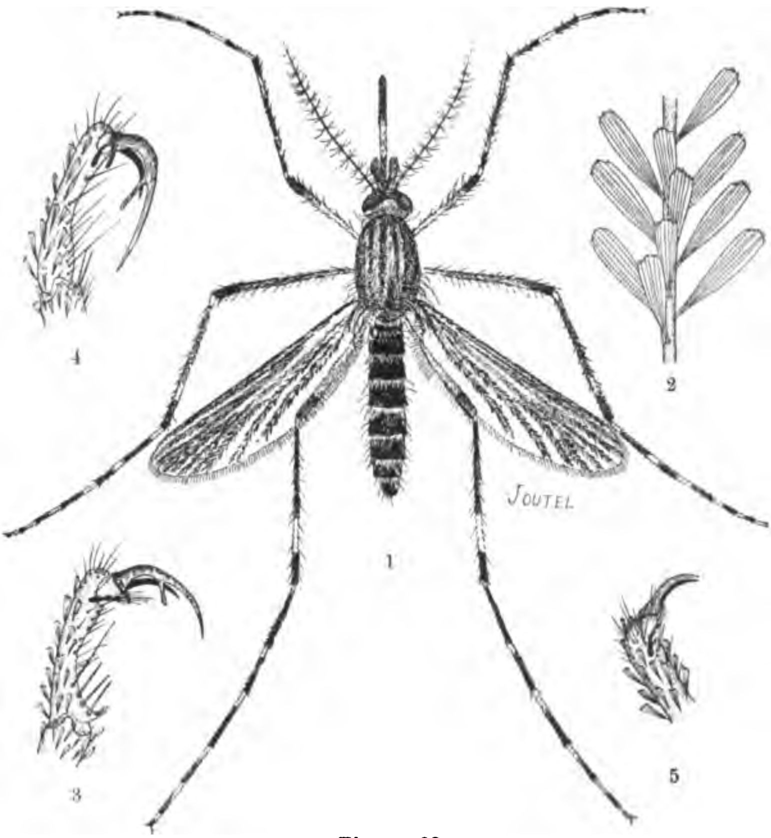

Figure 62.

Culex perturbans: 1, female adult; 2, part of wing vein showing scales; 3, anterior; 4, middle; and 5, posterior claws of male tarsi: all enlarged. (Original.)

The proboscis is dark brown with a yellowish central band. The palpi in the female are normal in shape, deep brown, with some yellowish scales; the terminal joint is very small, rounded and with three or four long bristles. In the male the palpi are only slightly dilated, the first two joints together as long as the pro-

boscis, the third joint the same length as the central one. The basal joint has mixed black and white scales, while the terminal two joints are blackish, with white at their bases. The fan-like tufts are dark brown. The antennæ of both sexes are dark brown, the plumes of the male fuscous.

The thorax is chestnut brown, with numerous yellowish scales over the surface, often forming irregular stripes. The pleura are brown, with a very few dirty white scales in small patches. The femora have mixed black and yellow scales, fewer beneath and at the base, with a black ring near the apex and a white knee spot. The tibiæ of the posterior legs are dark brown, almost black, with a broad white ring a short distance from the apex and narrow white rings at the base; the anterior and mid tibiæ may have indistinct bands, but are usually covered with black and whitish scales collected into spots and patches, sometimes forming two or more narrow, broken bands; the apices black. The tarsi are black, with broad, pure white bands at the base of the joints, and there is a whitish ring at the center of the first joint. The claws of the anterior and mid tarsal joints of the male are alike, each with a long claw having a median and basal tooth, and a small simple claw (fig. 62, 3 and 4). The posterior claws are equal and simple (fig. 62, 5). In the female they are alike on all feet, being equal and simple, like the posterior ones of the male. The wings are hyaline, with the veins densely clothed with large brown scales.

The abdomen is dark brown, with indistinct, yellowish basal bands, sometimes with white spots at the sides. Beneath it is yellowish, with brown scales.

Habits of the Adult.

Very little is known of this insect, though it is neither rare nor local, while the early stages are altogether unknown. Specimens have been taken by Mr. Grossbeck at Lake Hopatcong and by Mr. Viereck at Cape May, while Mr. Brakeley finds them literally by the hundred at Lahaway. The only male collected was taken at Lake Hopatcong by Mr. Grossbeck, July 21st, and the only female with developed ova was taken by the same gentleman in the Moonachie woodland swamp, July 29th. Of the hundreds of examples sent in by Mr. Brakeley during 1903 and 1904, between the last days of May and the early days of August, not one showed any traces of developing ova. Over one hundred examples were taken by Mr. Brakeley several times in each year at a single sitting in the early evening, and alto-

gether nearly 1,000 examples were examined by Mr. Dickerson and myself. There were large specimens and small specimens, fresh specimens and old specimens, specimens that had fed recently, some that had almost completely digested a meal of blood and some that had to all appearance never fed at all; but none with eggs in any stage of development and none with the characteristic inflated yet hollow abdomen of the female that has laid her eggs.

The larvæ have been sought in fresh water and salt, in clean water and foul; in the woodland and in the open; but up to the present time without success. Larvæ have been found whose adults are rarely or never seen, but that of this common species has escaped us thus far. Usually the species occurs in small numbers, though in 1903 it was several times sent in among the house mosquitoes, especially from Arlington; but in 1904 not an example was turned in, except by Mr. Brakeley, to whom we owe whatever knowledge we have of the adult. Mr. Brakeley believes that this is a migratory form, basing his belief upon the facts that, despite diligent collecting under varying conditions, he never found a male, and that they came in under the same conditions and with *cantator* and *sollicitans*. May 27th in 1903 and May 29th in 1904 marked the first appearance of the insects at Lahaway and a day or two later the swarm was in possession. It is not suggested that *perturbans* comes from the marshes; simply that it does not breed on the place and comes in from some outside point.

It is one of the fiercest and hardest biters that we have and Mr. Brakeley writes: "As against *perturbans,* undershirt, pants and drawers are no protection; they will bite clean through all." Nor are they at all timid or deliberate in the attack; but rather at once dive for the nearest point that offers a chance to make a puncture. They have no scruples about entering houses and for a time formed the only annoying species in Mr. Brakeley's office and bed room. I have already indicated that it was received from other points as a house mosquito. The latest date for the species is August 26th from Lahaway, while the earliest dates are those above given for the same place.

In order to determine, if possible, how generally this species was distributed, Mr. Brakeley collected in the late evening for a radius of half a mile or more from his house and found it everywhere, though not, of course, equally abundant in all places. Attempts to collect during the day proved failures, and incidentally proved that the insects do not seek concealment in the grass during the day. At early dusk they appear, coming apparently

from vines on trees and against houses; but always from above and always ready to bite.

The species sings and where many of them are about, the air is filled with an angry buzz that is quite unlike the preparatory note of any other species known to me.

Dr. Dupree, of Baton Rouge, told me that he had dissected a female with partly developed ovaries and that the eggs seemed like those of *pipiens;* but that would make this a species unlike in appearance to any other of which we know that it makes an egg boat. As to the method of hibernation, nothing is known save that we have never found it as an adult during the winter.

The Brakeley records would seem to indicate a single brood only, with a long life; but the occurrence of a male in late July and of a female with developed ovaries a little later, are pointers in another direction.

Fortunately the species is not of serious economic importance, though it is locally common.

CULEX TÆNIORHYNCHUS, WIED.

The Small Salt Marsh Mosquito.

This is a small black mosquito with narrow white bands at the base of the abdomen. The beak has a narrow white ring at its center and the legs are ringed with moderate bands of white at the bases of the tarsal joints; the last joint of the hind feet being entirely white. In worn specimens this insect might be taken for an undersized *C. sollicitans,* but can be separated at once from that species by the absence of the longitudinal stripe on the abdomen.

Description of the Adult.

This is a small mosquito, ranging between 4 to 5 mm.,=.16 to .20 of an inch exclusive of the beak, which is about 2.4 mm. in length. The head is dark brown with a few yellowish scales, which sometimes make a diffused patch in the angle formed by the eyes; the proboscis is blackish brown with a creamy white ring at about its center, slightly nearer the base. The palpi in the female are brown, becoming blacker distally, the extreme tips pure white; the terminal joint is small, almost rounded and covered with short, fine spines. In the male the palpi are shaped something like those of *C. sollicitans,* but are not so robust and the terminal joint is shorter; they are black in color, with narrow white rings at the base of the two terminal joints, and there is a

wider yellowish ring in the center of the basal joint. The fan-like tufts are brown with yellow reflections. The antennæ are brown in both sexes, the plumes in the male a pale brown color.

The thorax is brown, darker laterally, with some yellowish scales over the surface; the pleura, brown with patches of dirty white scales. The femora are black above, pale yellowish beneath, with a very few yellow scales; the black meets on the underside near the apex and the knee spot is a small yellowish dot. The tibiæ are black, spotted with yellow scales, and may be either

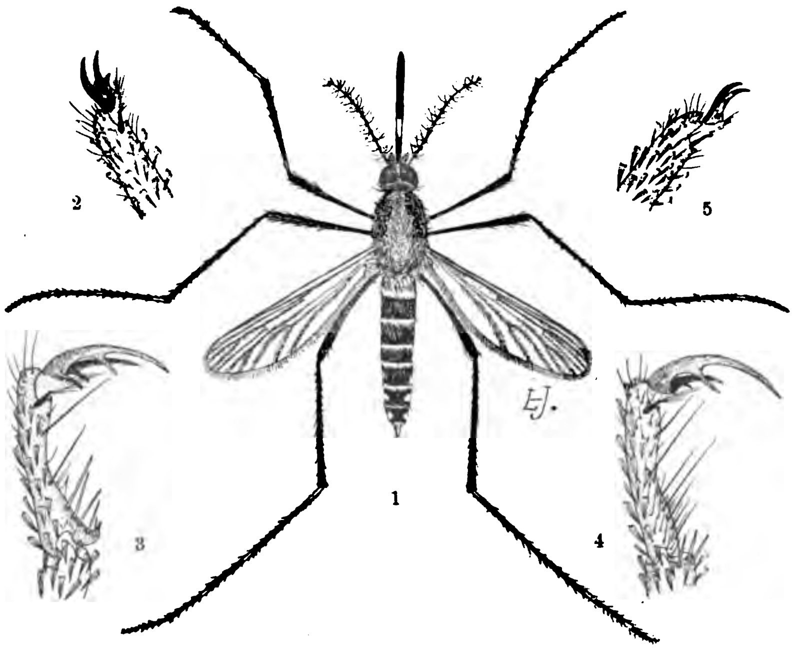

Figure 63.

Culex tæniorhynchus: 1, female adult; 2, the anterior claws; 3, anterior, 4, median, and 5, posterior claws of male: all much enlarged. (Original).

black or yellowish beneath. The tarsi are black, the anterior and mid narrowly white-ringed at the bases of the first three joints, obsolete or entirely wanting in the fourth, while the fifth, though without a band, is paler in color. The posterior tarsi have pure white bands about double the width of the anterior and mid, on all but the apical joint; that is entirely white or black tipped. The claws of the anterior and mid tarsal joints in the male (fig. 63, 3 and 4) are unequal in length, the long claw of the anterior having a median and basal tooth, the shorter only a single tooth near

the base, while in the mid tarsus each has but a single tooth. The posterior claws (fig. 63, 5) are equal, simple and rather sharply curved toward their apices. The claws of the female are equal on all feet, one toothed in the anterior and mid tarsal joints (fig. 63, 2) and simple in the hind pair as in the male.

The abdomen is black, each segment with a narrow basal band of white crossing the segments and with small lateral white spots beginning on the second segment, becoming larger posteriorly, till in the apical two or three segments they encroach well upon the dorsal surface. Beneath it is yellowish brown, apically banded with black.

Habits of the Adult.

In a general way, the habits of this species are like those of *sollicitans,* but it is not nearly so abundant. It is strictly a marsh mosquito, and has never been bred anywhere else, but it also migrates, though not so generally and not so far. It reaches New Brunswick from the Raritan meadows in small numbers, but it has never been sent in by Mr. Brakeley from Lahaway, so that it is distinctly inferior in its spread to both *sollicitans* and *cantator.* Nor is it equally abundant throughout its range. From the sections north of the Barnegat Bay, collections early in the season have shown few or no specimens: later they become more abundant; but from two to ten per cent. of the bred specimens was the best secured at any time from the collections made by Messrs. Brehme and Grossbeck. At Atlantic City I found the species active and biting during the day quite as abundantly as *sollicitans.* At Anglesea a series of porch captures in August made during the late afternoon, showed both species equally present. In the examination of Mr. Viereck's material some lots were nearly 50 per cent. *tæniorhynchus,* and in one lot of between four hundred and five hundred only five per cent. were *sollicitans,* the remaining 95 per cent. being of this species. These, however, are abnormal percentages, and on the marsh itself the captured adults show no such equality with the larger species. I have never observed *tæniorhynchus* crawl up the legs of the marsh tramper as its ally does, but it may do so where it is most abundant.

Mr. Viereck failed for a long time to find gravid examples of this species, but late in the season he collected a lot of specimens attracted to the electric lights and found them mostly gravid examples of *tæniorhynchus, sollicitans, salinarius* and *crucians.* He duplicated that collection later and thereafter found no difficulty

in obtaining specimens with developed ova. *Sollicitans* is also difficult to take when ready to oviposit, but it may be obtained by close sweeping of the grass in the early evening. *Tæniorhynchus* apparently refuses all invitations and hugs the ground until dark. Just why the light has a special attraction for gravid females it seems difficult to determine.

As to the bite, that is much like that of *sollicitans* and, like that species, *tæniorhynchus* takes no long thought in reaching a proper spot; any exposed place will answer and it has the same ankle-seeking propensity that its allies have. I have never taken it indoors, even along shore.

The egg-laying habits are like those of *sollicitans* and the eggs themselves have not been found separable from those of its ally. In fact in my first experiments I bred more *tæniorhynchus* than I did *sollicitans* from the egg-filled sods collected.

Description of Larva.

This larva which is figured on plate figure 64, with structural details, has *C. sollicitans* for its nearest ally and, though differing obviously in some of the details is, nevertheless, scarcely distinguishable from it in outline and color, besides its habits of breeding in the same pools. It is 7 to 8 mm.,=.28 to .32 of an inch in length to the end of the ninth segment and is dirty gray or yellowish in color. The head is one and one-half times as broad as long and usually of a pale yellow color; the sides and front shaded with brown and sometimes, though rarely, the sides of the vertex are bi-symmetrically marked. A faint crescent shaped mark, with a black spot in advance and four others to the rear of it are usually present, though it is common for one or more, or perhaps occasionally all, to be absent. (See figure 60, 7 to 12). On the front of the head are four single hairs arising from individual pits, each pair separated laterally, and there is a small tuft of four or five hairs at the base of each antenna. The antenna (fig. 6) is short and slender, with only a slight in and out-curve, the apical half dark in color, light yellowish toward the base and the surface with small scattered spines. The tuft has but two or three moderate sized hairs, and is situated on the shaft at about the middle; the apex has a few short bristles and one longer one, besides a small joint. The rotary mouth brushes (fig. 2) have the central hairs pectinated at the tip. The mandible (fig. 4) and the maxillary palpus (fig. 5) are similar to those of *sollicitans,* but the palpus is shaped a little differently and has a long apical tuft. The mentum is triangular with ten or twelve teeth

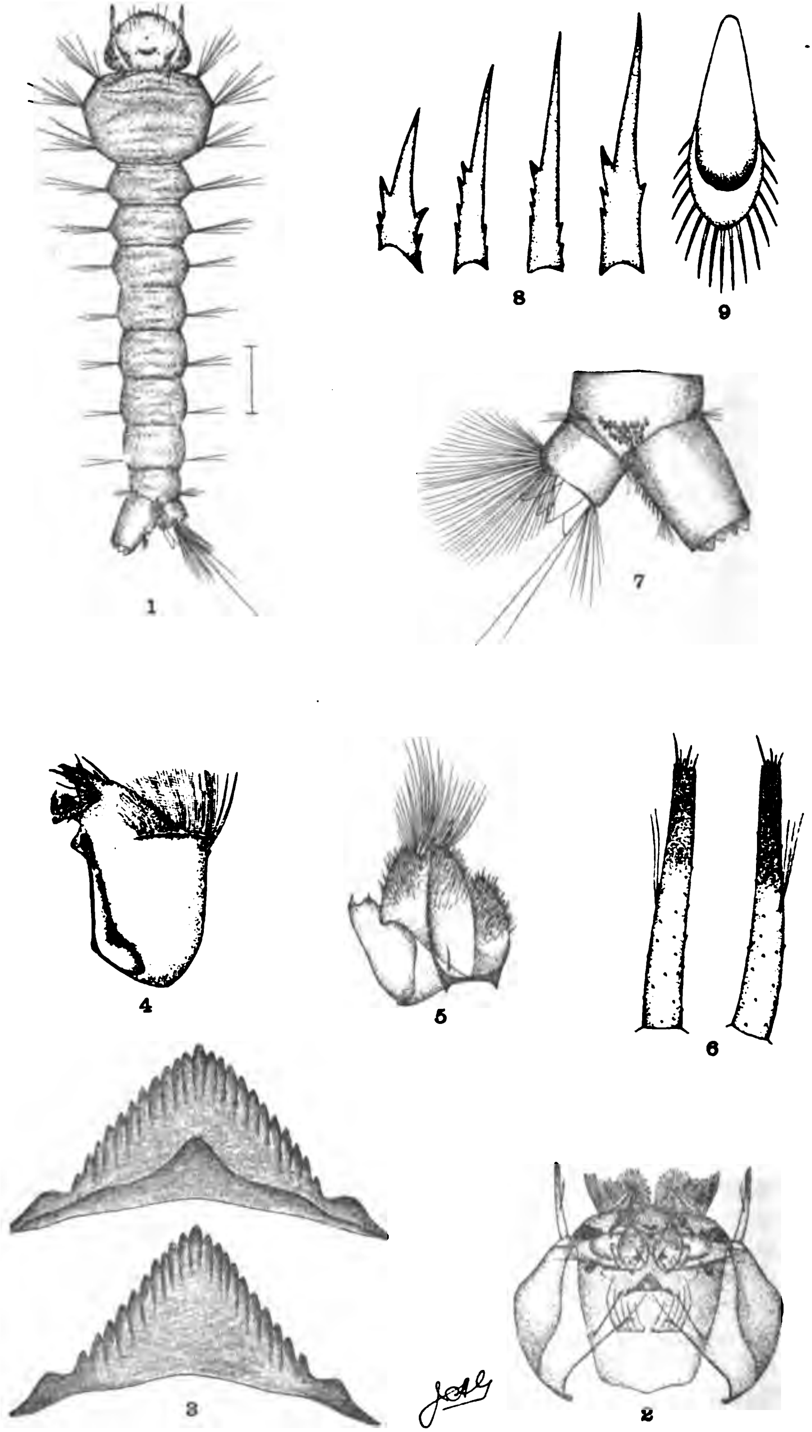

Figure 64.

Culex tæniorhynchus: 1, larva; 2, head from below; 3, mentum; 4, mandible; 5, maxilla; 6, antenna; 7, anal segments and siphon; 8, siphonal spines, showing variation; 9, a single scale of 8th segment: all much enlarged. (Original.)

on each side of the apex, and has very little variation in form, figure 3 showing the extremes; the differences being chiefly in the curve at the sides.

The thorax is wider than long, transversely depressed on the dorsal surface, the lateral hair tufts short and two very small tufts near the anterior margin.

The abdominal segments are normal, with four or five short hairs to the lateral tuft in the anterior two segments, fewer in the posterior ones. The eighth segment has small lateral patches of from sixteen to twenty-two oval scales, a single scale being shown in figure 9.

The anal siphon (fig. 7) is one and one-half times as long as broad or slightly less, and is grayish in color. The two rows of spines, from twelve to sixteen in each row, extend beyond the middle with a small terminating tuft. The spines are of moderate length, becoming short toward the base and are peculiar by being toothed on both sides. The ninth segment is square or broader than long, with the hairs of the double dorsal tuft and ventral brush shorter than normal. It is completely encircled by the chitinized saddle and the gills are very short; often no longer than broad.

Habits of the Early Stages.

These are like those of *sollicitans* and *cantator* and with their larvæ those of *tæniorhynchus* also occur. None of our collections show larvæ of this species only, though Mr. Viereck's material approached this point very nearly at one period. As a rule they are in the small minority. In a mass of partly grown larvæ there is little apparent difference between the three species, but when full grown the maculate heads of *cantator* and *tæniorhynchus* are characteristic, while between these the very short anal siphon distinguishes the latter.

Practically everything that has been said of the habits of the two other species above mentioned applies to *tæniorhynchus* as well. As the species is more southern in its range, *sollicitans* is its companion more frequently than *cantator*.

CULEX SQUAMIGER, COQ.

The Scaly Winged Mosquito.

The distinctive characters of this species are the very large size, jet black tarsi, with well defined white bands at the base of

the joints, the broad white bands at the base of the abdominal segments, the black marked thorax and the unbanded beak. The wings are not spotted but the veins are heavily ornamented with black and white scales.

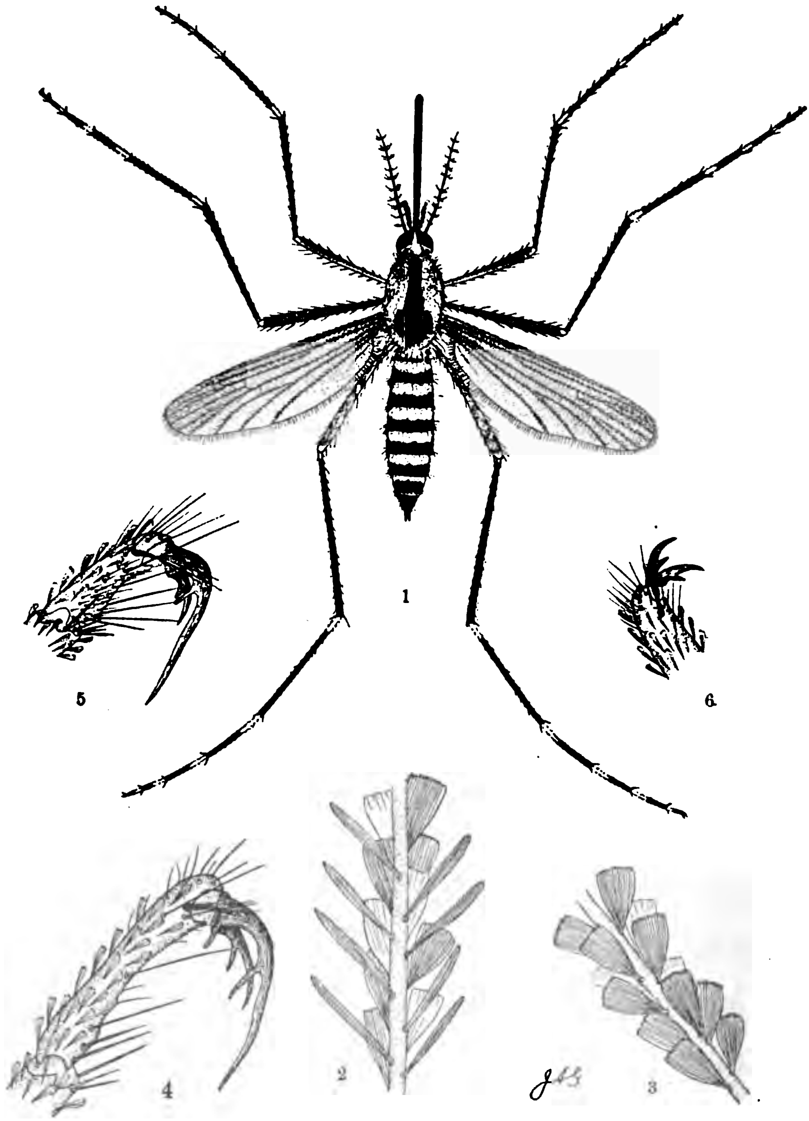

Figure 65.

Culex squamiger: 1, female adult; 2, part of wing vein near outer margin; 3, same near base, showing scales; 4, anterior, 5, median, 6, posterior claws of male: all much enlarged. (Original.)

Description of the Adult.

This is a large blackish brown mosquito, very robust in appearance. The body is 6 to 7 mm.,=.24 to .28 of an inch in length, exclusive of the beak and the wings expand about 14 mm., or almost three-fifths of an inch; the beak is not quite half the length of the body. The head is whitish in the posterior part, with patches of brown or blackish scales on each side of the center; the beak is black with a few scattered pale scales on the central and basal portions; the palpi in the female are slender, black in color, tipped with white, the terminal joint a small round knob with short spiny hairs. In the male they are brown or blackish, the basal joint white near the head, and with a yellow band in the center; the fan-like tufts are brown with yellow hairs at the base of the second joint and at the apex of the third joint. The antenna of the female is dark brown, while that of the male is paler brown with yellow reflections.

The thorax is grayish white with a dark brown median band, which is excavated in the anterior portion and sprinkled with a few golden brown scales. The other brown marks are on the sides of the band, posteriorly separated from it by narrow grayish stripes. This band is sometimes light brown anteriorly and mixed with the gray, giving the thorax a mottled appearance. The pleura are brown with patches of whitish gray scales. The femora have mixed black and yellow scales on the upper surface, fewer on the posterior side and are not collected into spots nor bands; their apices are yellow and beneath they are almost wholly yellow. The tibiæ are black except for a slight sprinkling of yellow scales, the posterior ones yellow at the knee. The tarsi are black with well defined white bands at the base of each joint in the hind feet and narrower bands on the first four joints of the mid and fore feet. The claws are one toothed on all feet of both sexes. Those of the anterior tarsal joint (fig. 65, 4) in the male, are stout, one about three-fourths the length of the other, the shorter one with the tooth nearer the base. The claws of the mid tarsal joint (fig. 65, 5) are, one short with the tooth at the middle and one very long, sharply curved at the basal third and the tooth situated in the inner angle. The hind pair of claws (fig. 65, 6) and also all those of the female are of equal length, with the median tooth slightly nearer the base. The wings are hyaline, the veins densely covered with broad, mixed black and white scales, and with many long narrow ones on the apical third of the wing.

The abdomen is black above with a few whitish scales intermixed; segments one to six are broadly banded with yellowish

white at the base, segment seven narrowly banded both basally and apically, tending to join at the lateral borders, the apical segment and genitalia black. On some specimens the bands break into the black irregularly. Beneath, the abdomen is yellowish.

Habits of the Adult.

This species was originally described from California and was first taken in New Jersey by Mr. Henry L. Viereck, May 8, 1903, at Westville, with a lot of *canadensis,* which were then flying. Later in the season it was taken in a low, swampy woodland near New Brunswick, by Mr. Clarence Van Duersen, June 28, July 16 and July 28. In 1904 Mr. John H. Voorhees took examples in the same woods during the latter part of June and until after the middle of July. They were always associated with *canadensis,* had approximately the same habits of flight and bit readily. They were not found to be especially vicious, however, and their bite was not more severe than that of the other species. No specimens have ever been taken outside of the woods and they are so rare there, that they cannot be regarded as in any way troublesome. Larvæ have been taken near Paterson by Mr. Grossbeck; hence it is perhaps a fair conclusion that the species occurs in favorable localities throughout at least the northern half of the State. The period of flight is long, and as we have no indication that there is more than one brood, the period of flight indicates an individual life of about three months.

Description of the Larva.

The larva is illustrated on plate figure 66, with details of structure. The full grown wriggler (fig. 66, 1) measures 12-14 mm., = .48–.56 of an inch in length excluding the anal siphon, is dirty gray in color, excepting the head and siphon and, in general build, resembles *Culex canadensis.* The head is almost as broad as long, widest just below the eyes, tapering without curve to beyond the base of the antenna, flattened in front, light brown in color and with four small black spots near the base of the vertex. On the anterior part of the vertex are four single hairs, each arising from separate pits; the pits so placed as to form a square, slightly narrower in front; directly opposite the posterior hair, at the base of each antenna, is a small tuft of four or five hairs. The antenna is rather short, curved, uniformly brown in color, the surface sparsely set with short, stout spines

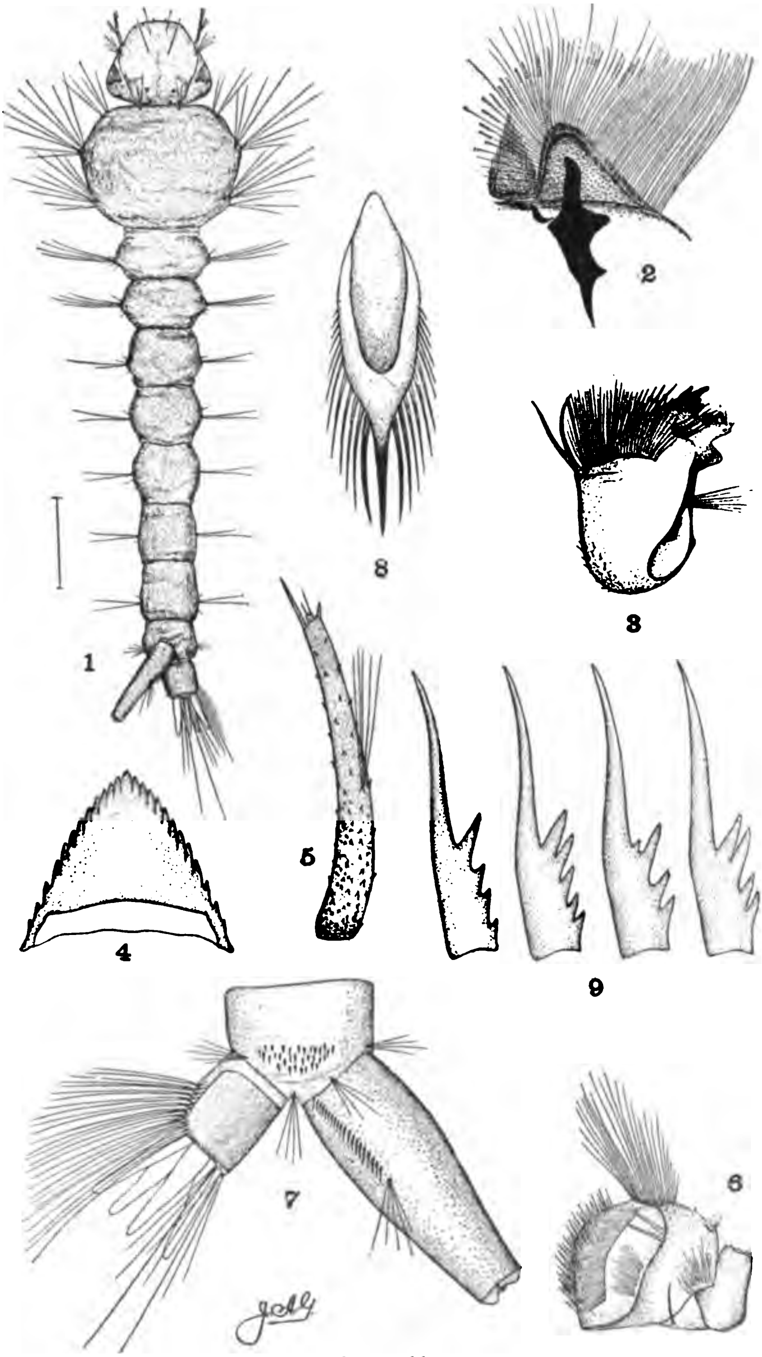

Figure 66.

Culex squamiger: 1, larva; 2, mouth brush; 3, mandible; 4, mentum; 5, antenna; 6, maxilla; 7, anal segments with siphon; 8, a single scale of 8th segment; 9, siphonal spines, showing variation: all much enlarged. (Original.)

with white ones on the narrow bases and broad apices of the first two joints, as well as on the narrow bases of the remaining joints of the middle tarsi; scales of the hind tarsi almost wholly white; all tarsal claws toothed. Wings grayish hyaline, the scales brown, lateral scales on the veins narrow and almost linear, petiole of first submarginal cell about two-thirds as long as this cell, hind cross-vein about its own length.

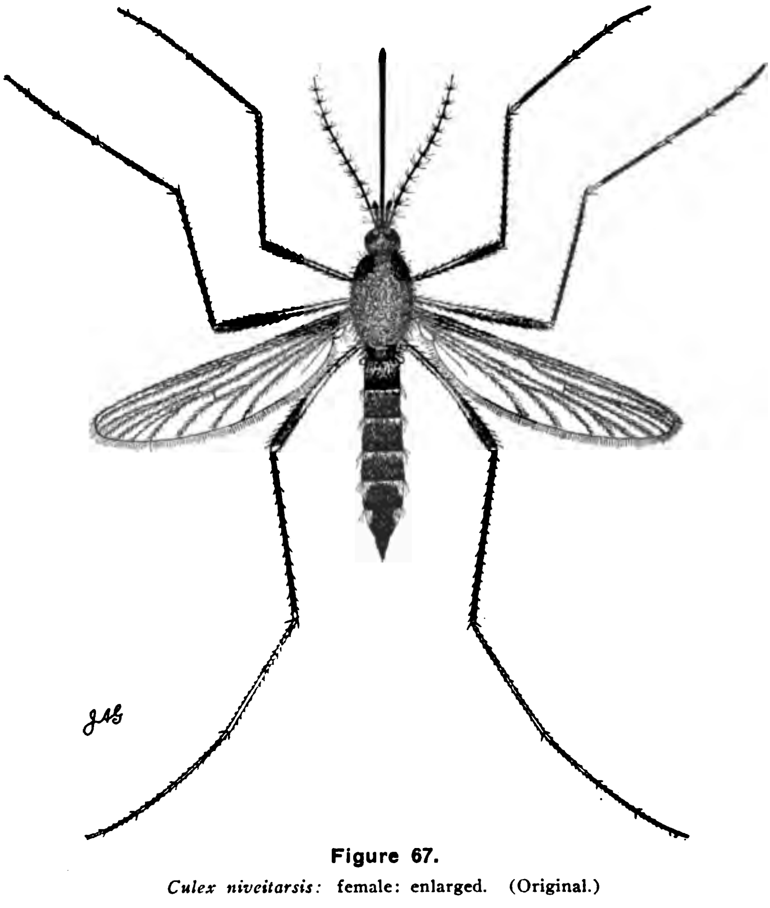

Figure 67.

Culex niveitarsis: female: enlarged. (Original.)

"Male: palpi slender, black, a broad band at middle of first joint and bases of the following joints white, proboscis reaching almost to apex of penultimate joint of palpi. Front and middle tarsi with one of their claws bidentate and the other unidentate, hind tarsal claws also unidentate; some of the brown bands on the hind tarsi quite distinct, especially the one on the third joint.

Petiole of first submarginal cell almost as long as that cell. Length, 4.5 mm. Otherwise as in the female."

Nothing is known of the habits of this species.

Description of the Larva.

The larva, with details of structure, is illustrated on plate fig. 68. It is a stout, robust wriggler and measures 7–7.5 mm., = .28–30 of an inch in length to the end of the ninth segment. In color it is grayish white, profusely mottled and shaded with brown. The head is about one and one-half times as broad as long, of a yellowish brown color. The posterior part of the vertex is maculated with a dark brown crescent-shaped spot, with a smaller one on each side. Six hair tufts of six or eight hairs each arise from the anterior part of the vertex, four in the central part and one at the base of each antenna. The single specimen from which the figure was made retained only two of these four central tufts, and the many small dots on the head were a preventative against ascertaining the presence or absence of pits. Later specimens showed the four tufts. The antenna (fig. 68, 4) is of moderate length, pale yellowish, becoming brown at the apical third, the surface is covered with rather large spines and many smaller ones intermingled; the apex with one long spine and three shorter ones besides a little joint. The tuft is situated on the shaft considerably below the middle and consists of eight or ten hairs. The rotary mouth brushes (fig. 68, 2) are deep orange in color, with the hairs of the central part pectinated at their tips. The mentum (fig. 68, 5) is triangular in form, twice as broad as high, with nine blunt teeth on each side of the apex. The maxillary palpus (fig. 68, 6) is normal, with a large apical tuft, a stout basal joint and hairs over the surface arranged in rows and patches. The mandible (fig. 68, 3) is normal and is peculiar by its very blunt teeth.

The thorax is rounded, with slight lateral angles, giving rise to moderate hair tufts; two very small tufts are also on the anterior margin. The dorsal surface is a little depressed and symmetrically blotched with brown. These markings differ as to shape, but always suggest two transverse bands, the anterior one broken in the middle.

The abdominal segments are thick and robust each with lateral tufts of two hairs each, except the anterior two, which have four or five hairs. The eighth segment has a large patch of small scales on each side, about forty-five in each patch, arranged in three or four irregular rows. The individual scale (fig. 68, 8)

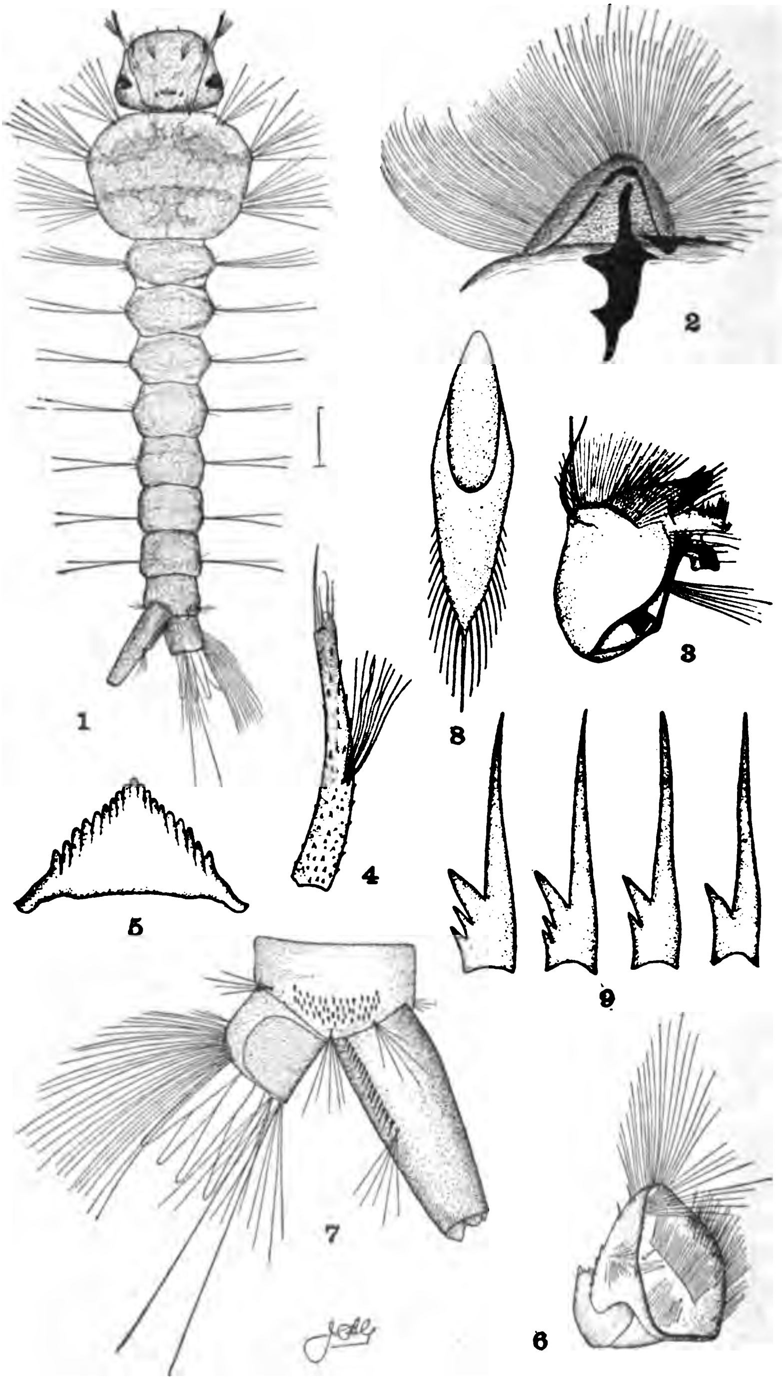

Figure 68.

Culex niveitarsis: 1, larva; 2, mouth brush; 3, mandible; 4, antenna; 5, mentum; 6, maxilla; 7, anal segments with siphon; 8, a single scale from 8th segment; 9, siphonal scales showing variation: all much enlarged. (Original.)

is rather long, broadest in the middle, with a small apical spine and lateral ones, becoming very small basally. The anal siphon is yellowish brown, about three and one-half times as long as broad, with the lateral rows of spines fifteen to seventeen in number, extending about half the length of the siphon from the base; the single spines are broad at the base with one large tooth, or with one or two smaller ones beside the large tooth (fig. 68, 9). The ninth segment is almost square, largely covered by the chitinized saddle; the double dorsal tuft and ventral brush are moderate, the latter with two small tufts below the barred area. The anal gills are one and one-half times as long as the ninth segment.

Habits of the Early Stages.

This seems to be one of the spring species, the larvæ being taken by Mr. Grossbeck May 9th and 14th in rocky pools on Garrett Mountain, near Paterson. On the 9th a mixture of larvæ and pupæ were taken, the larvæ being recognized as chiefly *canadensis,* a few *sylvestris* and one mature specimen recognized as theretofore unknown. May 12th a new species, *niveitarsis,* emerged from one of the pupæ, it was recognized as theretofore undescribed and the larva was put in alcohol. On the 14th another search turned out five additional larvæ of the new species, together with larvæ and pupæ, mostly *canadensis,* many *sylvestris* and a few *Aedes fuscus.* Two of the new larvæ were preserved in alcohol and the other three fell prey to some small Dytiscids which had been overlooked in the bottom material. One of the pupæ developed a *C. niveitarsis* and made the type pair from which Mr. Coquillett described the species. Persistent collecting later in the season failed to turn out additional material in this species.

CULEX CANTATOR, COQ.

The Brown Salt Marsh Mosquito.

This is a rather large, robust brown mosquito, in which the thorax is rather well covered with distinct spiny hair. The beak is not banded, the wings are not spotted, the tarsi are banded with white or whitish at the base of each joint, but the bands are not well marked and the merger into the ground color is gradual. The abdomen is banded with whitish, the bands rather indefinite and not constricted in the centre. Toward the apex they are rather diffuse and tend to cover the entire segments.

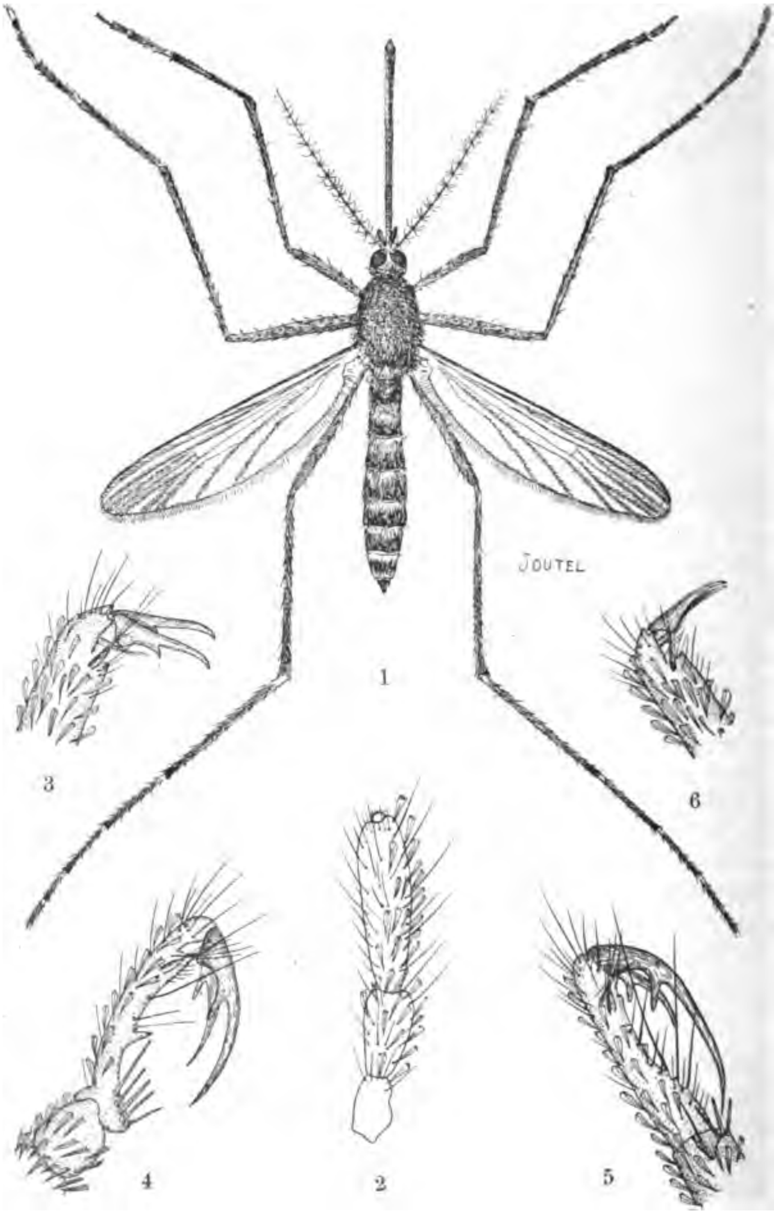

Figure 69.

Culex cantator: 1, female adult; 2, the palpus and 3, the anterior claws of same; 4, anterior, 5, median, and 6, posterior claws of male: all much enlarged. (Original.)

Description of the Adult.

This is a large mosquito, 7 mm., or a little over one-quarter of an inch in length, exclusive of the beak. The beak is 3½ mm., long or one-half the length of the body. Across the wings it measures 11 mm., or .44 of an inch. The head is yellowish brown, the sides and part of the top are taken up by the large black eyes; the beak is dark brown, almost black, without markings of any kind, the palpi in the female (figs. 69, 2) short, dark brown, four-jointed, clothed partly with scales and set with moderately long hairs, the apical joint small, knob-like and retracted. The male palpi (fig. 41, 6) are long, three-jointed, brownish black, paler at the base, without markings, thickly scaled and with fan-like tufts of hair toward the tip.

The antenna of the male is plumose, half as long as the palpi and brown in color, all the joints cup-shaped with a circle of long hair, except the two terminal ones; these long and slender, covered with short hair, and the base of the apical joint with six long hairs. The antenna of the female is longer, very slender, but with approximately the same number of joints, set with hair of irregular lengths and a circle of six long, bristle-like hairs at the base.

The thorax is reddish brown, clothed with short, upright, golden-yellow hairs. The legs are brown, femur paler, almost white, beneath with the knees white. The tarsi are blackish, all narrowly white-ringed at the base, the rings not well defined, merging into the black and becoming almost obsolete toward the tip on all feet.

In the male the anterior claw-joint (fig. 69, 4) is inwardly excavated and set with spines and bristles. The outer claw is smaller than the inner, but both have a single tooth in the middle, slightly nearer the base. The claw-joint of the mid tarsi is only slightly excavated and with claws the same as those of the anterior tarsi (fig. 69, 5). The posterior claw-joint is normal, very small, and with simple claws of the same size.

In the female the anterior and mid claw-joints are alike, with a single tooth on each of the claws. The posterior joint is of the same size but the claws are simple, as in the male.

The abdomen is dark brownish black, with yellowish white bands at the base of each segment, considerably narrowed centrally. The bands become wide laterally, more noticeable posteriorly, and at segment seven broaden to such an extent so as to entirely cover the dorsal surface. Beneath, the entire surface is pale yellow.

Habits of the Adult.

This species was not recognized as distinct until 1903, but was confused with both *cantans* and *sylvestris*. It was this fact that prevented its recognition as a migrant in 1902, when I first met with the species in great numbers and found it as early as April, the dominant form in South Orange. *Sylvestris* and *cantans* are both known as upland species, hence a local breeding place was sought and not found. Later in the season the breedings from the marshes turned out this species in numbers almost equal to *sollicitans,* from a wriggler much like that of the latter. At that time I insisted upon the distinctness of the species and, finally, Mr. Coquillett described it, calling it *cantator*—perhaps because of its general resemblance to *cantans*. In the Spring of 1903, I had abundant opportunity for observing it. As early as March 23d, larvæ were well advanced at the edge of the Newark Marsh, and adults began to issue during the early days of April. But it was not until the last days of the month that the bulk of the brood began to issue, and during the early days of May the migration was on in full force. May 12th, they had reached South Orange, and by the middle of the month the entire country was covered with them. A second and much larger brood became started on the marshes late in May, and before the end of June was fully a-wing. Migration began during the last days of June and, north and west, locality after locality was covered to an extent greater than usual. *Sollicitans* was also in this swarm which filled the cities and towns bordering on the marsh as they had rarely been filled before.

The early brood in the Raritan marshes had not been heavy and few specimens got as far west as New Brunswick; but the same conditions that started the June brood at Newark started that on the Raritan. Frequent trips by one or the other of my assistants had kept me fully advised of the developments, and I anticipated that by July 1st we might get our first supply. It came as expected; full measure, heaping and overflowing. On the morning of July 2d, I was met when I stepped outdoors by a famished horde containing *sollicitans, tæniorhynchus* and *cantator*. The preceding evening we had sat comfortably out on the porch, without disturbance from mosquitoes. The incoming horde settled the comfort for weeks thereafter.

This same brood was traced to Plainfield, Dunellen, Bound Brook and Somerville, where the migratory forms rarely get. How much further they spread in that direction I do not know,

but the Newark swarm was traced to Summit and Morristown, and may have extended further.

In 1904 marsh conditions favored the early brood and unusual swarms developed on the Raritan, Elizabeth and Newark meadows early in May; indeed the favoring conditions extended all along shore so that by May 10th the whole marsh area was awing, except along the Shrewsbury, where the work done by the Monmouth Beach and Rumson Neck Associations completely annihilated the immense brood that was developing. The ditches were completed just in time to do their work. At New Brunswick the swarm arrived May 12th, and extended onward. At Newark the invasion was almost unprecedented and compelled the closing of stores in some cases. This swarm not only reached Paterson, but covered the Garret Mountain, where Messrs. Dickerson and Grossbeck found them swarming June 11th. It was reported further that it had extended to Bernardsville, which is well up in the hills, and far enough back to be beyond the reach of ordinary migrations. So in the Pines, *cantator* reached Lahaway May 17th, weeks ahead of the 1903 record.

Further details of this character will be found under the general heading "Migrations" on a previous page.

There is one feature in which *cantator* differs from the other migratory forms, i. e., both sexes fly together for some distance and occasionally females with developed ovaries are found far from any point where they can deposit them with any hope of development. The males are seen for a day or two only, but they arrive with the females and are evidently able to stand a flight of several miles at least. In Newark and Elizabeth both sexes may be taken on first arrival in equal numbers; at New Brunswick the males are numerous enough to "dance" in small swarms just at dusk. From Lahaway no males have been sent and my records are not sufficiently complete to give the limit of male flight.

While, as has been noted, occasional females with developed ovaries are found at some distance from shore, yet this is a feature only in the early arrivals; *i. e.*, they occur during the week or two after a flight and disappear, none being found during the later days of the brood's stay. Whether they make their way back to the marshes to oviposit, or whether they lay their eggs in the most likely place to be found, is not definitely known. As the percentage of such females is larger in Newark and Elizabeth than in New Brunswick, it is quite probable that many find their way back, and as an occasional brood of the larva

is found above the marsh line, it is possible that some may lay eggs which in most instances fail to develop.

In New Jersey *cantator* dominates the Newark, Elizabeth and Raritan meadows early in the season. If the year is favorable, the early start will carry this dominance to midsummer or even through the summer. At the Barnegat shore *cantator* shares with *sollicitans* the early honors, but becomes steadily less as the season advances, leaving *sollicitans* in almost sole possession. At Atlantic City and Cape May I found no *cantator* during the period when they were swarming further north, though the species does occur there in small numbers throughout the summer. Mr. Brakeley's records show that they must have bred on the Mullica River marshes in greater number than *sollicitans* during the present year; but that is probably the southern limit of their dominance, and in ordinary seasons it does not extend so far. Just why they should be more plentiful on the northern marshes I do not know, nor what prevents their development along the southern shore.

In 1903 I found no appearance of *cantator* dominance south of Sandy Hook; in 1904, as soon as the May swarm developed, I sent Mr. Brehme along the Barnegat shore to Manahawkin, where he found them everywhere, while I sent Mr. Dickerson to Cape May and went myself to Atlantic City, finding only *sollicitans* in both places. Twice, in June, I visited Cape May and at neither times found *cantator*.

Cantator enters houses freely where they are open; but is easily kept out by ordinary screening. It does not seek opportunities, but when attracted by light or the human odor it will come indoors much more readily than *sollicitans*. Among the indoor captures by Mr. Buchholz, this species is well represented througout the season, scarcely yielding at times to *pipiens*. It comes to porches readily enough and does not hesitate about getting into the breeziest corners.

As a biter, *cantator* stands in the front rank, and it is persistent in its attack. It does no unnecessary singing and is not especially deliberate in chosing a point of attack. It proceeds to business at once, and while its bite is not so "hot" as that of *sollicitans*, i. e., it does not give the intense burning sensation, it is really more painful and more lasting in its effects.

It might be added that this species flies during the day and bites when opportunity offers; but it is not so active as *sollicitans* in this respect and rises only when disturbed. It is essentially an evening mosquito.

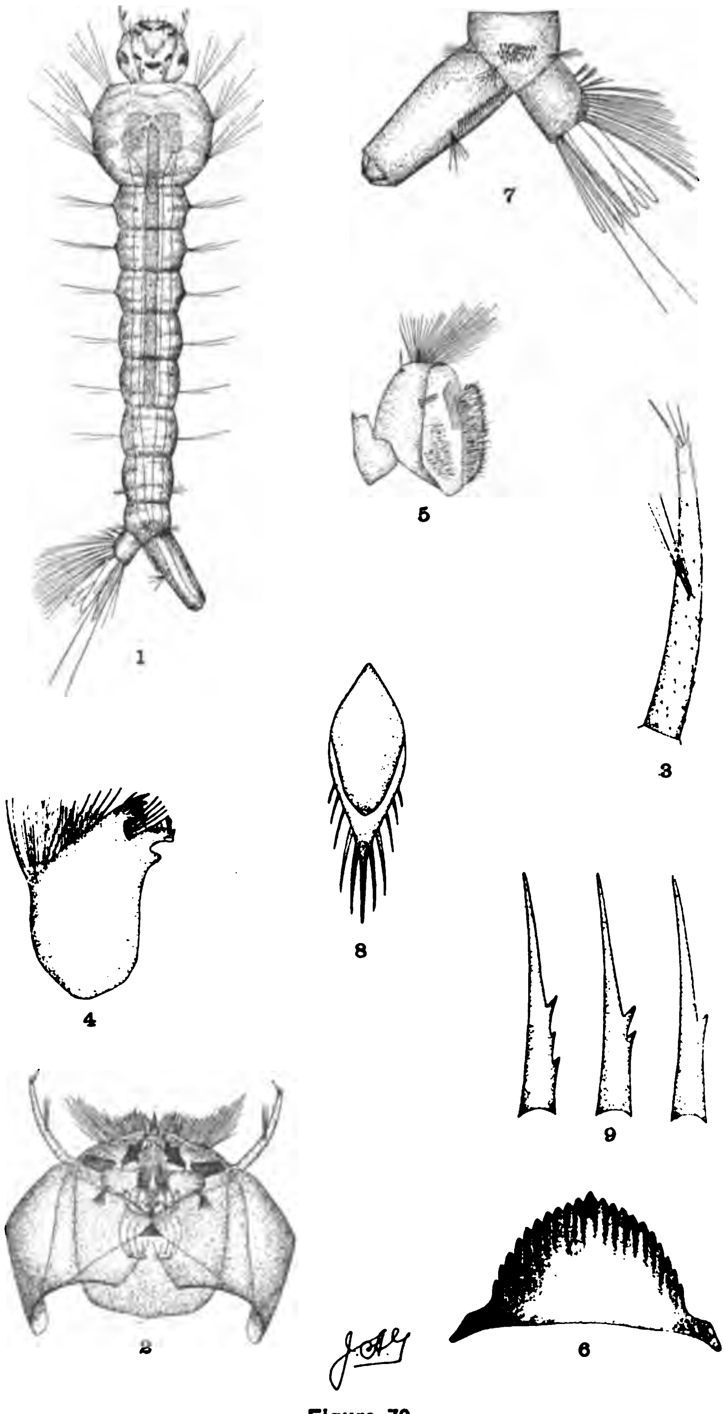

Figure 70.

Culex cantator: 1, larva; 2, head from below; 3, antenna; 4, mandible; 5, maxillary palpus; 6, mentum; 7, terminal joints and siphon; 8, a single scale from 8th segment; 9, siphonal spines: all much enlarged. (Original.)

CULEX CANTANS, MEIG.

The Brown Woods Mosquito.

This is a large brown mosquito which resembles *Culex cantator,* but the bands of the legs and abdomen are broader and whiter. The beak is unbanded and the wings unspotted.

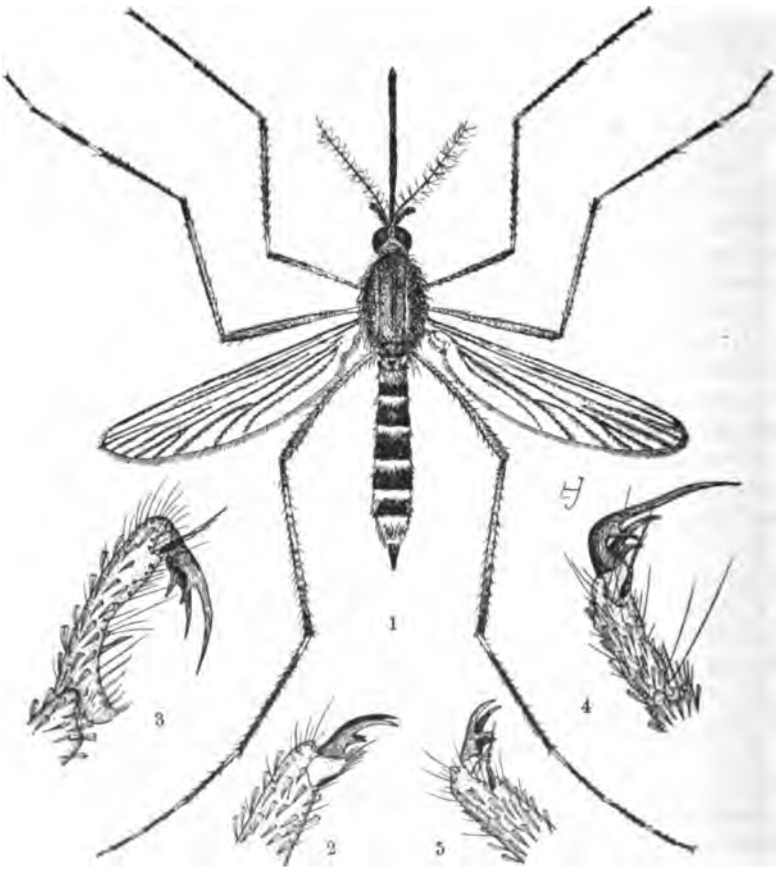

Figure 71.

Culex cantans: 1, female adult; 2, the anterior claws; 3, anterior; 4, middle, and 5, posterior claws of male: all enlarged. (Original.)

Description of the Adult.

This is one of the larger species of *Culex* occurring in New Jersey, and at first glance looks like an oversized *Culex cantator.* The body, exclusive of the beak, is 7–8 mm., = .28–32 of an

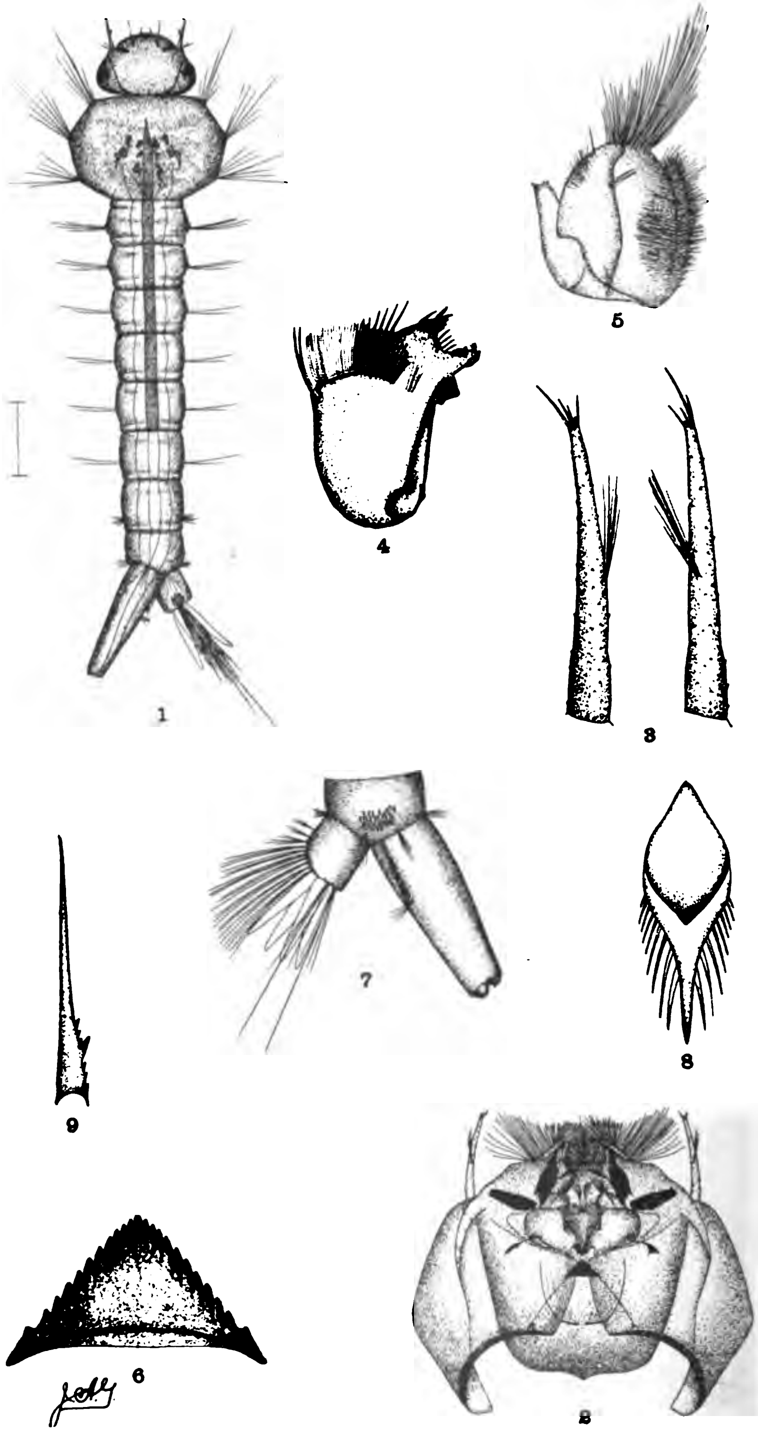

Figure 72.

Culex cantans: 1, larva; 2, head from below; 3, antenna; 4, mandible; 5, maxillary palpus; 6, mentum; 7, terminal joints and siphon; 8, a single scale from 8th segment; 9, a siphonal spine: all much enlarged. (Original.)

inch in length, the beak is about one-third the length of the body, and the wings expand 12 mm., or about half an inch. The head is dark brown, with scattered creamy yellow scales and a distinct creamy border to the eyes. The palpi in the female are brown, four jointed, the apical one small, oval in shape, pointed at the apex and distinctly spiny or hairy. In the male (fig. 41, 4) the palpi are wholly brown, the basal joint twice as long as the two apical ones taken together. The antenna of the male is plumose, paler than the palpi, with shape and number of segments as usual. The female antenna is normal.

The thorax is dark brown, covered with short, upright scales, the yellow ones scattered over the surface, often collected into stripes. Legs with the femora pale brown, darker at the apex, and yellowish beneath; the tibiæ with mixed yellow and brown scales, dark brown at the apex; the tarsi dark brown, almost black, broadly white banded at the base of the joints in the posterior legs. In the mid-tarsi the bands are narrower and almost lost in the anterior ones.

In the male the claw joint of the anterior tarsi (fig. 71, 3) is excavated inwardly, with one long claw and a shorter one, each with a median tooth, nearer the base. The mid claw joint (fig. 71, 4) is short, not excavated, with a very long and a short claw, each with a single tooth near the base. The claws of the posterior tarsi (fig. 71, 4) are small, of equal length and each with a single claw. The claws of the female (fig. 71, 2) are alike on all feet, somewhat longer than those on the male posterior feet and with one tooth on each.

The abdomen is blackish brown, broadly banded at the base of the segments with creamy white, which sometimes encroaches a trifle on the apex of the anterior segment. The bands become broader toward the sides, more so posteriorly, until they connect at the sides and the apical segments are often wholly white. The bands are very broad in the male so that the abdomen appears white, banded with black. The under side of both sexes is dirty white.

Habits of the Adult.

Little is known of the habits of this species in the adult stage. It is as early on the wing as *canadensis*, occurs in the same places and bites just as hard. And having said this, I know in addition only that after the middle of May nothing more is seen of the insect. Its life seems much shorter than that of *canadensis* and it seems not to range far from the place of its birth. Of its biting

habits I know only that it does bite, that the pain is slight as compared with that of *cantator,* which it resembles so closely that the two have been supposed to be the same species. There seems to be only one brood.

Description of the Larva.

The larva and its parts are figured on plate fig. 72. The larva when full grown is from 9 to 10 mm., or .36 to .40 of an inch in length, excluding the anal siphon, is of rather stout build and usually dirty slate gray in color except the head, which is yellowish brown. The head is one and one-half times as broad as long and immaculate except for a faint cloud which is usually present on the vertex. From the center of the head arise two small hair tufts of two hairs each and a single, short hair in advance of each; another tuft of five or six hairs is at the base of each antenna. The antenna (fig. 72, 3) is yellowish at the base, becoming dark brown toward the tip; it is rather short, with a slight curve, and is swollen for one-fourth its length from the base, then evenly tapered to the apex; the apex with four spines, a long and a short slender one, two short stout ones and a little short articulated joint. The tuft is situated on the shaft slightly below the middle and consists of six or eight hairs which do not reach the tip. The surface is sparsely set with moderate spines and numerous small ones arranged in rows. Eyes rather small, sometimes with a small posterior portion separated from the rest. The hairs of the rotary mouth brushes (fig. 72, 2) are numerous and heavily pectinated, especially centrally. The mentum (fig. 72, 6) has from nine to thirteen teeth on each side of the apex, is triangular in form, with the toothed edges only slightly curved. The mandible (fig. 72, 4) is normal and the maxillary palpus (fig. 72, 5) is oval with a moderate sized tuft of long hair at the apex, hair patches on its surface as usual and the basal joint large with small spines at the apex.

The thorax is angulated, one and one-half times as broad as long, the lateral angles with tufts of long hairs arising from tubercles and the anterior margin with two very small tufts of two or three hairs each.

The abdominal segments from one to seven are subquadrate in form, with four or five lateral hairs on the first and second segments, two hairs each on segments three to six inclusive, and the seventh and eighth segments with short tufts only. The lateral combs of the eighth segment have from twenty-six to fifty scales, each arranged in a patch without regularity. The lateral spines

fringing the individual scale are long, as shown in figure 72, 8. The anal siphon is about three times as long as broad (fig. 72, 7) with a double row of toothed spines, sixteen to twenty-two in each, eighteen being about the average. The teeth are small, generally with a large one in the middle and are confined to the basal third of the spine. The ninth segment is only slightly longer than broad, with the barred area of ten or twelve tufts of hair on the ventral part and the two dorsal tufts with one long hair each. The anal gills are moderately long, without obvious trachea.

Habits of the Early Stages.

Larvæ nearly full grown were collected on the outskirts of Newark by Mr. H. H. Brehme, March 28th and April 2d. The first pupa appeared April 3d, the first adult on April 6th, and others continued to appear until April 12th. Full grown larvæ and pupæ were collected by Mr. Grossbeck at Morristown, May 1st and adults began to issue from these May 3d. In both collections *canadensis* predominated and so far as our information goes the habits of the early stages are the same in both. Collections with larvæ of that species were made also at Arlington, Cranford, Elizabeth and Preakness Mountain, all in April or very early May, and it is probable that throughout the more northern part of the State *cantans* and *canadensis* occur together in early Spring. Mr. Brakeley has never found the species at Lahaway and it does not occur there, nor anywhere in the pine belt so far as we know. It cannot be considered a troublesome species from present experience.

A peculiarity of the larva is that it favors the deeper pools and feeds and hides among the dead leaves covering the bottom. This renders collecting rather a tedious task and makes it easy to overlook them on a surface examination because they rarely come to the top and do not stay there long. The pupæ, however, are always at the surface, as in allied forms.

CULEX SIPHONALIS, GROSSBECK.

The Brown-striped Woods Mosquito.

A species closely resembling *Culex cantans* but smaller, darker in color and with a brown line or stripe in the center of the thorax. The abdominal bands are grayer than in that species and much more diffused.

Description of the Adult.

This is a medium-sized mosquito, measuring 5–6 mm.,=.20 –.24 of an inch in length, including the beak, which is just about half the length of the body. The head is brown, with the occiput covered with pale yellow scales which extend forward between the eyes; the palpi in the female dark brown, four jointed, terminal joint small, oval in form, pointed at the apex and slightly spiny; the proboscis pale brown with dark brown scales scattered

Figure 73.

Culex siphonalis: 1, anterior, 2, median, 3, posterior claws of male; 4, anterior claws of female: enlarged. (Original.)

over the surface, entirely covering the apical fourth. The male palpi are similar to *canadensis* in shape, brownish, with a pale band in the center of the basal joint and at the two terminal ones; the fan-like tufts dense, silky brown in color. The antennæ are brown in both sexes, the basal and two succeeding joints in the female testaceous.

The thorax is covered with mixed pale yellow and brown scales at the sides and with a median stripe composed wholly of

brown scales, the pale scales of the sides sometimes forming a narrow border to this brown stripe; the pleura brown, clothed with patches of dirty white scales. The femora are yellowish beneath and at the extreme apex on the upper side, the remainder covered with mixed black and white scales; the tibiæ and the first tarsal joints blackish brown, sprinkled with whitish scales, all the other tarsal joints black. The fore and mid tarsi are narrowly ringed with white at the base of the joints except the fifth one in the anterior feet; the posterior tarsi with broad basal bands of pure white. The claws of the anterior tarsal joint in the male (fig. 73, 1) are very stout, unequal in size and each with a large median tooth; those of the mid tarsal joint (fig. 73, 2) are unequal, the larger long and slender with a long blunt tooth one-third its length from the base, the smaller with a median tooth near the base. The posterior claws (fig. 73. 3) are equal, each with a median tooth nearer the base. In the female the claws are equal and slender on all feet, with a single long tooth near the base of each.

The abdomen is blackish brown with pale yellowish bands at the base of the segments and extremely narrow apical ones at the base of the posterior three segments, irregularly merging into the brown, becoming diffused at the sides until, beneath, the scales are mixed together indiscriminately, the white ones predominating. The bands of the male are very wide, mixed with brown scales and tend to cover the entire posterior segments.

Habits of the Adults.

Nothing is known of the habits of this species in the adult stage. The only specimens at hand were bred from larvæ and, though frequent collections were made at the places where the larvæ were found no specimens were ever taken. We know, of course, that it is a woods mosquito and it probably never gets away from their shade. We know also that it is an early species and the probabilities are that there is only one brood. Mr. Coquillett believes that this species is like *cantans;* but there seems to be no difficulty in discriminating between the two when the thoracic vestiture is complete.

Description of the Larva.

The larva, plate figure 74, fig. 1, measures 9–11 mm.,=.36–.44 of an inch in length exclusive of the anal siphon when full grown, and is not robust in appearance. The body is a light

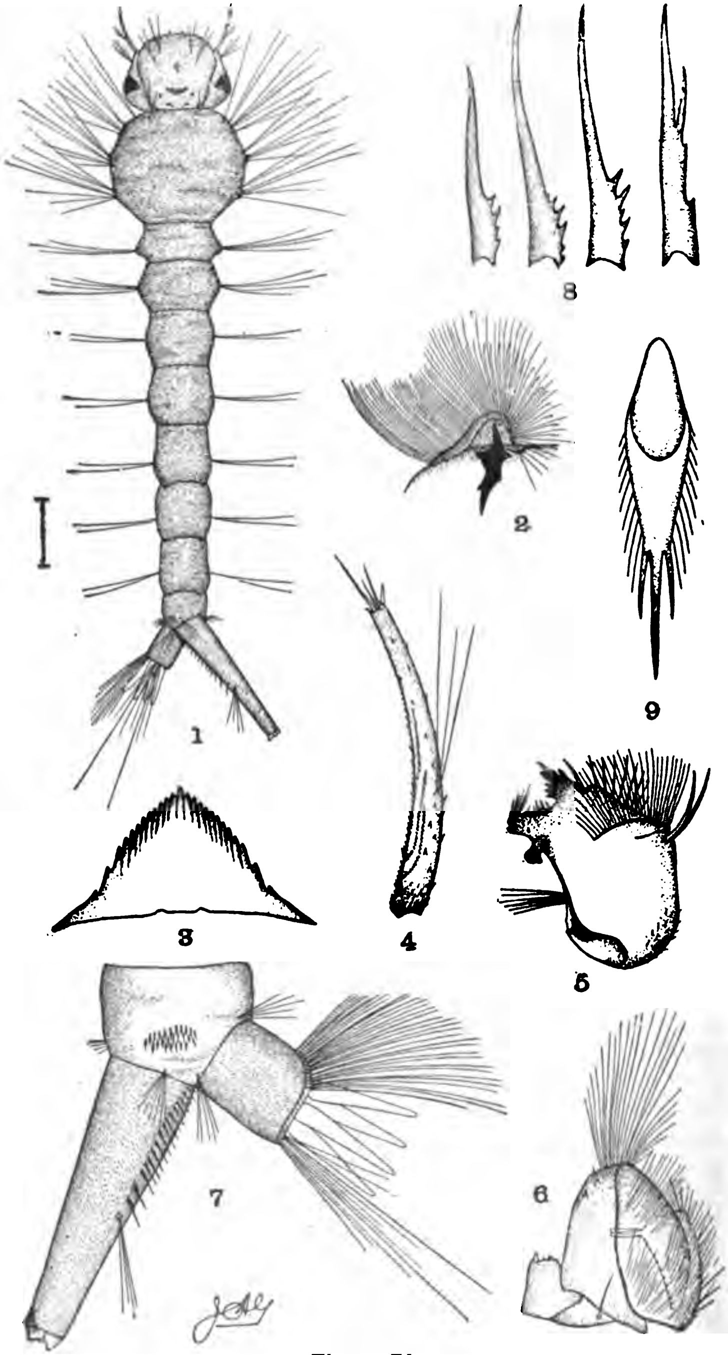

Figure 74.

Culex siphonalis: 1, larva; 2, the mouth brush; 3, mentum; 4, antenna; 5, mandible; 6, maxillary palpus; 7, terminal segments and siphon; 8, siphonal spines; 9, a single scale of 8th segment: all enlarged. (Original.)

gray or yellowish brown in color with the thorax somewhat darker. The head is about one and one-half times as broad as long, yellowish to light brown, though the vertex is often darkly clouded so as to give the appearance of a dark brown head. The posterior part of the vertex has a maculation of four spots and a semi-circular blotch, which are often obscured by the clouds. Four tufts of two hairs each are situated on the top of the head in the anterior part and a larger tuft is at the base of each antenna. The antenna (fig. 74, 4) is moderately long, somewhat sharply curved, the surface sparingly set with spines, rather thickly at the base, and three or four regular rows of minute spines run from the base toward the apex on the inner side. The tuft is well below the middle and consists of but two or three hairs. In color the antenna is brown, very dark toward the tip, the apex with three spines of different lengths, a very short spine and a small joint. The eyes are large and black and the rotary mouth brushes (fig. 74, 2) are pectinated in the central hairs. The mentum (fig. 74, 5) has slightly curved edges of eleven or twelve teeth on each side of the apical one, and becomes very broad at the base. The mandible (fig. 74, 5) is normal, with a group of small spines at the base. The maxillary palpus (fig. 74, 6) is set with spines and patches of hair over the surface and has a chunky little joint at its base.

The thorax is as long as broad, only slightly angulated at the sides, the lateral tufts moderately long and, in addition, there are two very small tufts on the anterior margin.

The abdominal segments from one to seven are oblong or subquadrate in form, with three or more hairs to the lateral tuft in the first and second segments, and two hairs to the tuft in the following segments. The eighth segment has from twenty-four to thirty scales to each of the lateral patches; the single scales long, with three spines at the apex and very fine ones along the sides. The anal siphon (fig. 74, 7) is pale yellow in color, slightly darker near the tip, very long, being about five times as long as its width at the base and evenly tapered toward the apex. The spines, from fifteen to twenty-two in each row, extend almost to the middle; they vary in size, and in the number and length of the teeth as shown in figure 74, 8; the short ones always toward the base; the apical two longest and separated from the rest and from each other. The siphonal tufts at the end of the row have but three or four long hairs. The ninth segment is slightly longer than broad with the usual dorsal and ventral tufts. The anal gills are stout and moderate in length without visible trachea.

The larva differs obviously from that of *cantans* in the antennal structure, in the form and arrangement of the scales on the eighth segment and in the form and armature of the anal siphon.

Habits of the Early Stages.

Four larvæ, rather well grown, were collected by Mr. Van Dursen April 25th, in the swampy woodland at Livingston Park, with *Culex canadensis* and *Corethra cinctipes*. They were at once recognized as distinct and separated from the others; but they did not do well; two died and on May 7th everything that remained was put in alcohol. April 27th another collection of twenty specimens was made and May 2d as many more were brought in. The larva was not easily found, occurring only in deep pools with a layer of leaves on the bottom, among which they feed and hide. Pupation began May 4th and on the 7th there were twelve pupæ; but then a fungus attacked the remaining larvæ and all were put in alcohol. The first adult emerged May 8th and all were out May 12th, giving a pupal period of from four to five days.

There was no later appearance of larvæ and it is probable that there is one brood only, the winter being passed in the egg stage.

CULEX SYLVESTRIS, THEOB.

The Swamp Mosquito.

A medium sized or small mosquito, with the tarsi narrowly white ringed at the base of the joints; the beak is unbanded and the wings unspotted. The abdominal segments have bands of pure white at the base, constricted in the center and narrowed at the sides.

Description of the Adult.

This is a mosquito of medium or small size, ranging from 4 to 5.5 mm., = .16 to .22 of an inch in length, excluding the beak, which is about half the length of the body. The head back of the large black eyes is golden brown, with small lateral patches of black and white scales; the proboscis is dark brown, black toward the tip, without markings of any kind; the palpi in the female are normal, dark brown, white at the apex, with a very small fourth joint, somewhat flattened and retracted. The male palpi are similar to *C. canadensis*, but stouter, blackish brown in color, with a white band in the center of the basal joint and another, rather broad white band at the base of the two terminal joints. The fan-like tufts are normal in size and the central joint extends one-third its length beyond the tip of the beak.

The antennæ are brown in both sexes, that of the female yellow at the basal two or three joints.

The thorax is dark brown, with many golden yellow scales evenly scattered over the surface; the pleura are paler brown, with a few small patches of white scales. The femora and tibiæ are deep brown, yellowish beneath; the base of the femora and knee-spots also yellowish; the tarsi brownish black, with very narrow whitish rings at the base of all joints, except the last

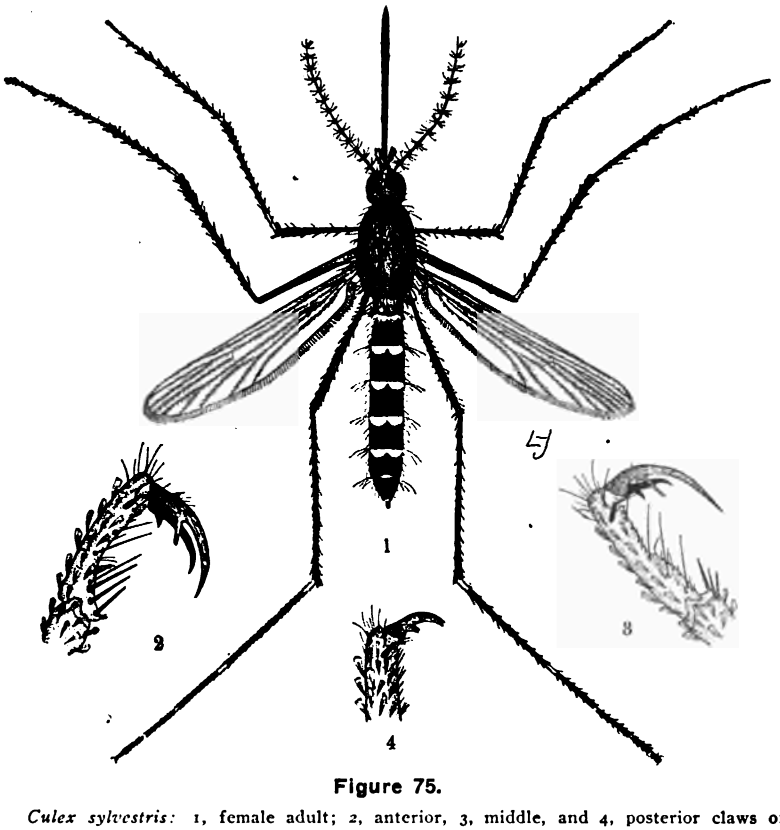

Figure 75.

Culex sylvestris: 1, female adult; 2, anterior, 3, middle, and 4, posterior claws of the male: all much enlarged. (Original.)

in the front and mid legs. The claws of the male in the anterior and mid tarsal joints (fig. 75, 2 and 3) are unequal in size, the larger with a long median tooth, the smaller with a short basal tooth; the posterior claws (fig. 75, 4) are equal, each with a median tooth nearer the base. In the female the claws are alike on all feet, equal and with a single tooth, as in the male posterior feet.

The abdomen in the female is dark brown, with the band at the base of the segments constricted in the center and toward the sides, where it joins the lateral markings, which extend upward from the venter, so as to appear as two lunules placed side by side. The penultimate segment has in addition to the basal band a narrow apical one, slightly prolonged forward in the middle; the last segment with a small apical band only. In the male the banding is similar, but the bands are almost or wholly divided in the center and join the side markings without the lateral constrictions. Beneath the abdomen is creamy white, with incomplete brown apical bands.

Habits of the Adult.

This is one of the species that delights in porches and gardens and does its share toward the end of the season in making life miserable. It gets indoors quite readily, but makes no especial effort to do so; *i. e.*, it will get through an open door or window, but will not attempt to crawl through screens or work through crevices. It bites readily, but not very viciously, the results being on the whole less painful than from either *pipiens* or the salt marsh species. In appearance it is a small black mosquito, with narrowly white-banded legs and banded abdomen. The character of the abdominal bands, being constricted and almost divided in the middle, forms one of the most certain means of recognizing the species. There is considerable variation in size, but on the whole it looks smaller and chunkier than either *pipiens, cantator* or *sollicitans*. When rubbed, a large specimen is sometimes very like *cantator* in appearance.

It occurs throughout the State and throughout the season, though early in the year it is found only in small numbers, and is rarely troublesome in towns or about houses. Later, in August and early September, it is often the dominant species, even close to or at the shore. Mr. Viereck reports it as one of the troublesome species on porches at Cape May, and further inland it replaces the salt marsh forms as an extra-territorial species. Although not a migrant like *sollicitans* or *cantator,* nevertheless *sylvestris* is not a strictly local pest and often appears a considerable distance from any known or possible breeding place. A mile or two is an easy proposition for the species and five miles is not outside of its possibilities. It seems, however, to move as an individual rather than in considerable bodies and the increase in numbers is gradual; there is no sudden appearance of a swarm overnight. So the disap-

pearance is equally gradual, isolated specimens remaining in town until early October and in the field much later.

The adults die off gradually as winter advances and hibernation is in the egg stage. The eggs are deposited singly on the surface of the water and sink to the bottom, or they may be placed at the edge of a low pool or in the moist mud of a depression from which the water has evaporated. As to the length of adult life, this is probably considerable; but no definite experiments were made and the period of nearly three months is based upon field observations only. At all events it is not a brief one and is reckoned by weeks rather than days.

Description of the Larva.

The larva varies greatly in size, measuring from 6 to 8.5 mm., = .24 to .34 of an inch in length, exclusive of the anal siphon. The figures on plate 76 were drawn from a large sized larva. Full grown specimens are yellowish or grayish in color throughout, but when young are almost white, except the head, which is yellow. The head is broadest immediately below the eyes, tapers anteriorly and is rounded in front. There are six small hair tufts of four or five hairs each on the anterior part of the vertex; one at the base of each antenna, the others more central, one pair to the rear of the other. The maculation of the head varies immensely, though it is always symmetrical; figures 19 to 24 on plate 60, show some of the forms, all of which are common and may be present in a single lot. By far the commonest form, however, is that shown at figure 24; a defined brown patch in the center of the anterior part of the vertex and another smaller one in the center or posterior part of the vertex, on a yellow ground color. Entire lots often have this form of maculation, and as there are no other species with similar markings it usually identifies the larva. In young and half grown larvæ the heads are wholly pale yellow, save for a slight mark in the center. The antenna (fig. 76, 5) is rather short, curved, thickest at the base, tapering apically; the surface set with stout spines, the color yellow, becoming darker toward the apex. The apex has one long and short spine, two bristles and a small joint. The tuft is situated on the shaft one-third from the base and consists of six or eight hairs. The rotary mouth brushes (fig. 76, 2) are dense, orange colored and have the hairs pectinated in the more central part. The mentum (fig. 76, 6) is triangular in form, with from twelve to fourteen small teeth on each side of the apex. The mandible (fig. 76, 4) and the maxil-

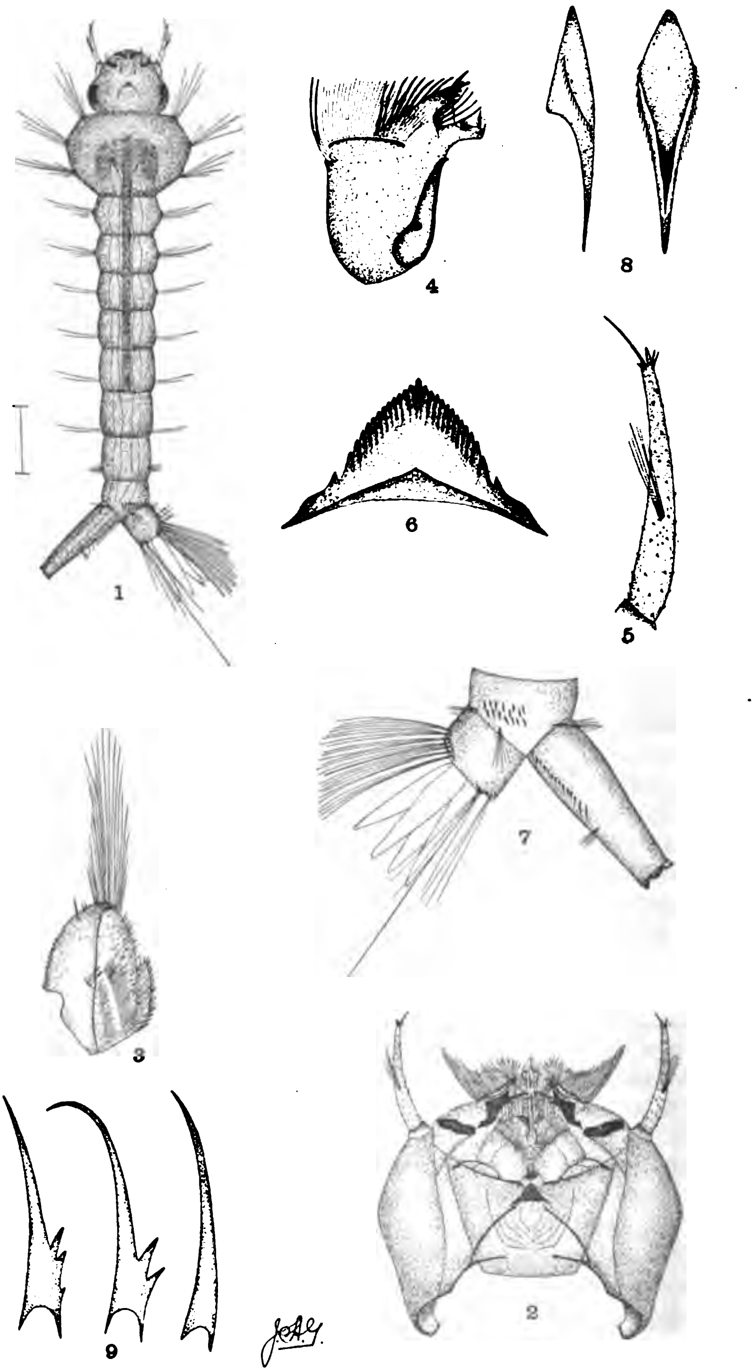

Figure 76.

Culex sylvestris: 1, larva; 2, head from below; 3, palpus; 4, mandible; 5, **antenna;** **6,** mentum; 7, terminal joints and siphon; 8, single scales from below and side; **9,** siphonal spines, showing variation: all much enlarged. (Original.)

lary palpus (fig. 76, 3) are normal, the latter with a stout basal joint, which is not shown in the drawing.

The thorax is broader than long, angulated at the sides and with rather small sized tufts arising from the angles.

The abdominal segments have lateral tufts of hair, four or five in each in the two anterior segments, two each in the succeeding ones, the seventh with short tufts only. The eighth segment has lateral patches of scales, about ten or twelve in each, though there may be as many as fifteen, arranged in an irregular double row; the single scale is rather broad, pointed at the apex and fringed at the sides with fine, short hair. The anal siphon is two and one-half to three times as long as broad at the base and dirty yellow in color; the lateral rows of spines consist each of from fourteen to eighteen spines extending half the length of the siphon from the base, the terminal two separated from the rest and from each other. The individual spines are usually two or three toothed, but occasionally one toothed or even simple, as shown in figure 9. The ninth segment is almost square, not quite ringed by the saddle; the double dorsal tuft and ventral brush are normal, the latter with several small tufts below the barred area. The anal gills are about twice as long as the ninth segment.

Habits of the Early Stages.

Larvæ of this species occur almost everywhere except on the salt marshes or in positively foul water. They are common in woodland pools, tho second to *canadensis* there, and they are dominant in open swamp areas. In the Passaic Valley, specimens appear in early April and in the Great Piece meadow every pool will be found loaded with larvæ at almost all times. The eggs do not seem to hatch evenly in Spring and young larvæ will be found when there are already pupæ in the same pool. So, not all the eggs laid by one female seem to hatch during the same season or at one time. Some may lie over until next year, but the majority hatch, because there is a steady increase in number with each brood. Just how many broods there may be in one season depends on weather conditions. As early as May 9th, Mr. Grossbeck found adults plentiful in the Garret Mountains, near Paterson, and large larvæ in the pools. May 21st, there was a young brood in the pools in the Great Piece Meadows and in early June, broods were found in the woodland pools along the Whippany River near Morristown, and in the Orange Mountains. Late in June full grown larvæ were in the pools on the Preakness Mountain, near Paterson, and before July 1st the adults were out in

force. In the Black River Swamp they were found in the same condition at about the same time and so, on June 30th, mostly pupæ were found in woodland pools on the borders of Spring Lake, near Trenton. July 21st, there was a young brood in the pools surrounding Lake Hopatcong, and a few days later mature larvæ and pupæ were taken everywhere in pools in the Hackensack Valley. The entire Passaic and Hackensack Valleys were kept under observation during 1903, as were also those large swamp areas in Essex and Morris Counties and always *sylvestris* was the dominant species. Captures of adults sent in from this territory always showed *sylvestris* present, and that species breeding in a swamp area at Vailsburgh, become common in the sendings of adults from Montclair and South Orange.

From the region of the Delaware the open marsh areas almost always turned out *sylvestris* in numbers. Mr. Grossbeck found it the dominant species between Trenton and Bordentown. Mr. Seal sent it in by the hundred from the swamp areas near Delair and toward the river. Mr. Viereck found the species along the Big Timber Creek region and in the marsh areas south of Camden. He also found it in the Cape May inland swamp region. This is, therefore, essentially a swamp species, but it does not occur in deep or dark swamps. Mr. Brakeley never found it in the huckleberry swamps of Lahaway and indeed rarely sent in the species in any stage, nor did I find it in my cranberry swamp collections.

By far the greater number of larvæ were taken in permanent water areas, but many of the woodland pools in which it occurred were temporary in the sense that they usually dried out before the summer was over. It was never sent in from gutters or lot rain pools or from foul waters at any time. Mr. Viereck found it once in a barrel at Cold Spring, Cape May County. In New Brunswick a brood was found in a lot pool August 12th, larvæ being mature and pupæ already present; a second brood was found September 23d in a similar stage and there may have been a brood in the interval. This is a low springy place, which rarely dries out entirely and which fills readily with even a light rain. The latest collections of larvæ were made during the early days of October, adults emerging about the middle of the month.

As for the habits of the larvæ they offer nothing that is peculiar. They are dependent upon atmospheric air and hence are readily destroyed by any of the oil coverings. The pupal stage varies in length according to temperature, but is usually short—two or three days during the summer.

This species ranks fairly among the pestiferous forms, but it is less troublesome than any of the others. It is not so readily controlled, however, as the house mosquito and sometimes causes trouble in jurisdictions outside of those in which it breeds. The methods of dealing with it are elsewhere set out.

CULEX SIGNIFER, COQ.

The White Lined Mosquito.

A medium sized black mosquito with the hind tarsi broadly white banded at each end of the joints, the last one being entirely white; the bands of the front and mid-tarsi are very narrow, if present at all, and are confined to the apices of the joints, save the first one on the mid-tarsi. The beak is unbanded. The thorax is black, marked with narrow white lines. The wings are grayish, with a distinct white spot at the cross vein, and the abdomen is dark brown, with white lateral marks which tend to cross the dorsal surface.

Description of the Adult.

This is a mosquito of moderate build, measuring 5–5.5 mm., = .20–22 of an inch, in length, excluding the proboscis, which is not quite half the length of the body. The head is velvety black with some white scales scattered on the central part and a clearly defined white border to the eyes. The proboscis is narrow at the base, becoming dilated toward the tip; black, with white scales scattered at the sides, forming a black median line. The palpi in the female (fig. 77, 2) are a little over one-third the length of the proboscis, three jointed, the basal two joints long and slender, black with a few white scales, the terminal one very small and wholly white. In the male (fig. 41, 7) the palpi are slender, as long as the proboscis, three jointed, the basal joint long, the terminal one very small; in color black with some white scales, the base of the second joint and all of the third white; a few long bristles on the last two joints. The female antennæ are black with scattered white scales; in the male they are black with silky brown plumes.

The thorax is velvety black with fine white hairs over the surface and long lateral black ones; there are two bluish white, narrow dorsal vittæ on the anterior two-thirds; two similar arcuate lateral ones extending the entire length of the thorax and two broken ones on the posterior half which extend forward

between the lateral and central ones. The pleura are blackish with a few white scales collected into small patches. The femora and tibiæ are black with white scales sparingly scattered over the surface, their apices and base of the tibiæ in the posterior legs white, the bases of the femora yellowish, especially on the under side. The anterior and mid tarsi are black, usually without rings, though the extreme apices of the joints and the base of the first joints of the mid tarsi are pale and often distinctly yellowish. The posterior tarsi are broadly banded with pure white at both ends of the joints, and the last one is wholly white. The claws of the male anterior and mid tarsal joints (fig. 77, 4, 5) are unequal, the larger with a long blunt tooth one-third from the base, the smaller with an extremely small acute tooth near the base; the posterior claws (fig. 77, 6) equal and simple. The female claws are equal and simple on all feet. The wing veins are clothed with brown and white scales, giving the wing a grayish appearance. On the radius and media, at their connection with the cross vein, are white scales only, which together form a distinct white spot; the scales on the basal half of the anal vein are also white.

The abdomen is brownish black with considerable variation in the banding. There is always a large white spot, sometimes divided transversely in two on the basal segment, which is confined to the dorsal surface. The following three segments have narrow, ill defined basal bands which are often entirely obsolete; the apical three segments have wider bands which become broad laterally and join the side markings. Small patches of white scales are sometimes near the apical margins of the penultimate and antepenultimate segments. The venter is brown, with diffused whitish bands at the base of the segments, the sides more clearly marked with white joining the bands of the dorsum.

Habits of the Adult.

Practically nothing is known of the habits of the adult. It has never been taken, indoors or out, by any of the collectors, although they have collected in the localities where the larvæ were found. So far we have only bred adults out of larvæ coming from Delair, Camden County, and Chester, Morris County. The larva only has been taken at Lahaway, Ocean County.

The mosquito is a very pretty one when examined under a magnifying glass, and by its narrow white lines on the thorax recalls the yellow fever mosquito; indeed, it was at first placed in the same genus—*Stegomyia*. There is nothing about it to indi-

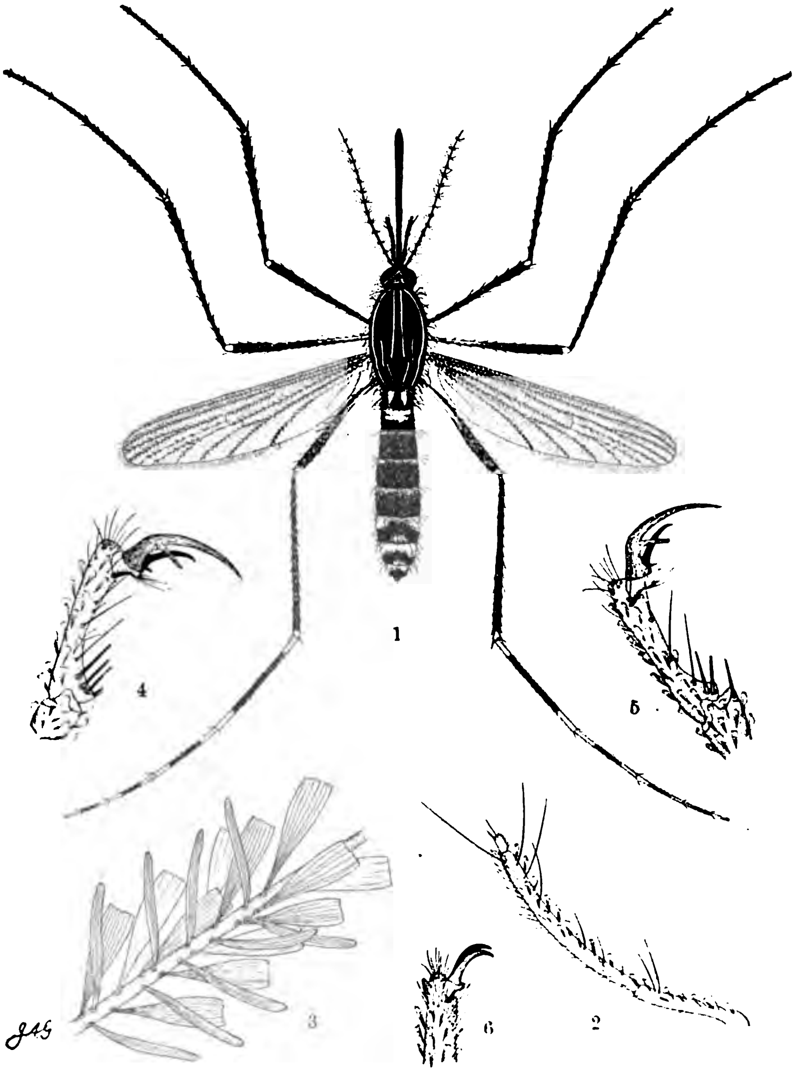

Figure 77.

Culex signifer: 1, female adult; 2, palpus; 3, part of the wing vein showing scales; 4, anterior, 5, middle, and 6, posterior claws of male: all enlarged. (Original.)

cate that it cannot bite; but so long as it remains so rare the question is hardly to be considered important.

Description of the Larva.

The larva, with details, is illustrated in figure 78. It is a stout, chunky wriggler, and when full grown is 7-8 mm.,= .28-.32 of an inch, in length, exclusive of the anal siphon. It is grayish black in color with the thorax somewhat lighter, except the head, siphon and dorsal plating. The head is purplish black, as long as broad, and has straight sides, rounded in front and at the base. Six equally spaced hair tufts of five or six hairs each are in a transverse row on the anterior part of the vertex, the four central ones slightly to the rear and the lateral two very close to the base of the antennæ. The antenna (fig. 78, 2) is short, dilated at the basal third, tapers toward the tip, and the apex has two long spines, two smaller ones and a little articulated peg. The surface is destitute of spines or hair and the tuft is situated on the shaft a little over one-fourth from the base, consisting of about six feathered hairs. The eyes are small, transverse and surrounded by a yellowish ring. The rotary mouth brushes (fig. 78, 5) are orange or yellowish in color and composed of simple hair. The mandible (fig. 78, 4) is normal and the maxillary palpus (fig. 78, 3) is rather broad, square at the base, with an obtuse apex and a large apical tuft; the basal joint long and slender. The mentum (fig. 78, 6) is an almost equilateral triangle with a large apical tooth, then five or six small lateral ones, blunt at the tips, and four very large pointed ones below these. There are usually nine teeth on each side of the apex, but occasionally one has ten.

The thorax is wider than long and is very thick, the anterior angles somewhat sharply angulated. The six lateral hair tufts are moderate in size and there are two small tufts near the anterior margin.

The abdominal segments are oblong or subquadrate in form, with five or six hairs to each lateral tuft in the two anterior segments and very slight tufts in the succeeding ones. The sixth segment sometimes has a small, dark brown chitinized plate on the dorsal surface; on the seventh, a similar plate covers the entire surface, save a slight anterior and posterior margin, and extends down the sides below the middle. On the eighth segment this plate is narrowed, corresponding to the smaller dorsal surface, and extends lower down the sides than the preceding one. The lateral combs are at the posterior margin of the

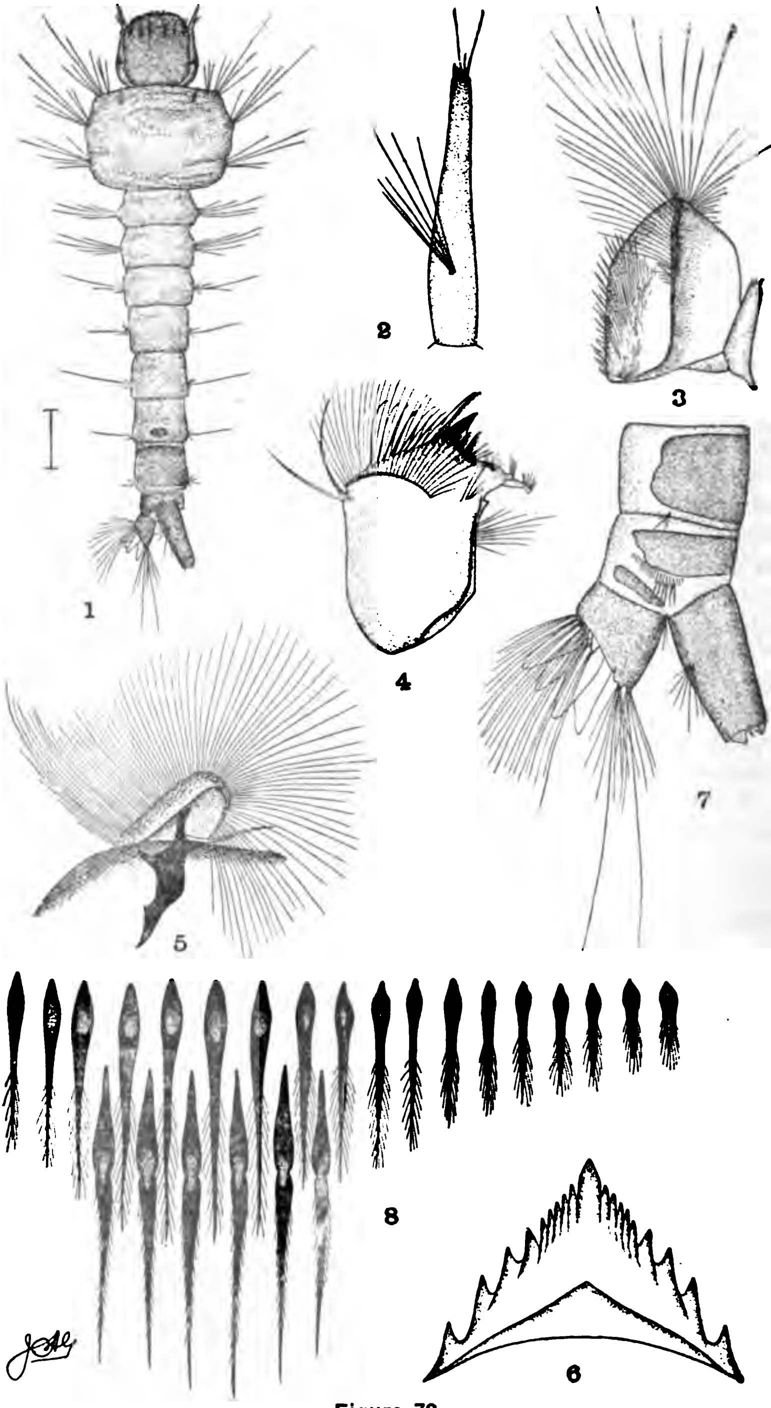

Figure 78.

Culex signifer: 1, larva; 2, antenna; 3, palpus; 4, mandible; 5, mouth brush; 6, mentum; 7, terminal segments showing dorsal plates and siphon; 8, the scale patch of 8th segment: all enlarged. (Original.)

plate, but are not joined to it. They consist each of two rows of scales: the first with from fifteen to twenty-one greatly elongated ones, fringed laterally at the basal half with fine hair, the longest scales toward the venter; the second with six or seven scales, their apices extending between those of the anterior row. The individual scales of this row are much longer than any of those of the first and are constricted at about one-third from the base; sides fringed as in the others. A small lateral plate is between the combs and the posterior margin of the segment. The anal siphon is about three times as long as wide, almost black in color and evenly tapered toward the apex. It is without lateral rows of spines, but has a hair tuft at about the middle. The ninth segment is small, with an oblique posterior margin; the double dorsal tuft and ventral brush are normal, the latter confined to the barred area. The anal gills are short, about three times as long as broad.

Habits of the Early Stages.

Nothing is known of the egg laying habits of this species, but the indications are that oviposition is on the surface or at the edges near the surface. The larva is so characteristic and so unlike the other species of *Culex* that there should be no difficulty in recognizing it. Mr. Seal writes: "*Stegomyia signifera* made its appearance in small numbers among *Culex pungens* in much larger numbers. This occurred in a tub of rather foul water sitting under an apple tree in a chicken yard. There were three developments of this species, all in the same place, although there were over twenty other tubs of water nearby." The occurrence with *pungens* in a tub indicates a surface oviposition. Although I have had pails with water of almost all degrees of foulness exposed in my back yard, I never found even a single representation of this species.

Harold Marsh found them near Chester in a tree hollow September 5th, in company with *triscriatus,* and again October 3d. They were fully mature in both cases, and of the September lot some were already in the pupal stage, most of the adults appearing within a week. The water in which these larvæ were found was not notably foul. It may be that these pools in decaying trees are the more usual breeding places and that the eggs are laid something like those of *triscriatus*. At all events several broods are indicated.

CULEX ATROPALPUS, COQ.

The Rock Pool Mosquito.

This mosquito has not as yet been found in New Jersey. It has been taken in Maine and New Hampshire and also along the Potomac River, Maryland; thus New Jersey is within the faunal range of the species and its occurence, therefore, is probable. It

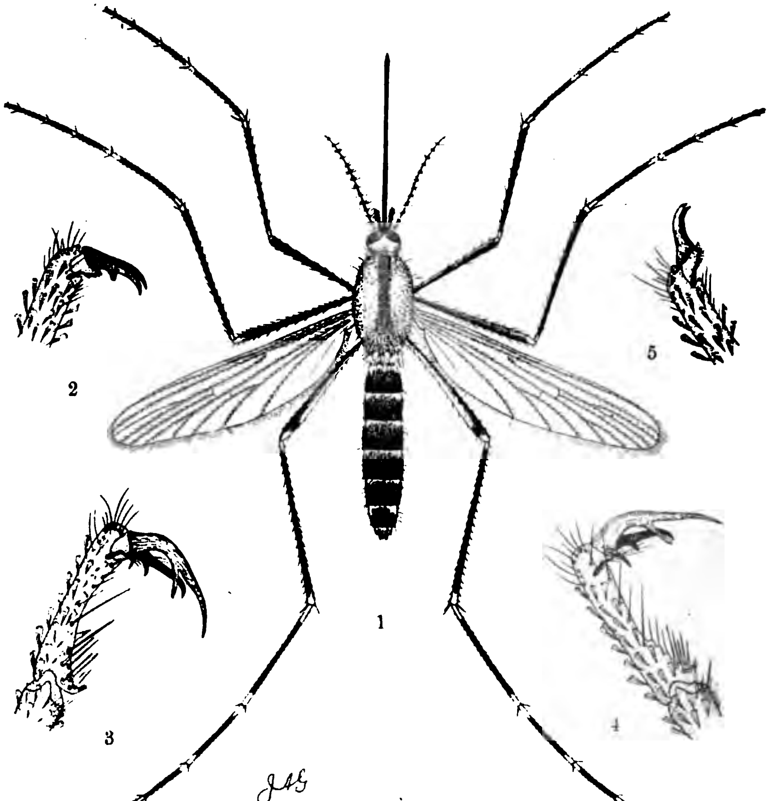

Figure 79.

Culex atropalpus: 1, female adult; 2, anterior claw of same; 3, anterior, 4, middle, and 5, posterior claws of male: all enlarged. (Original.)

is closely allied to *C. canadensis,* the tarsi being ringed with white on both sides of the joints except in the last two of the hind feet and the last three of the fore and mid feet; the last joints of the hind pair are wholly white. The beak is unbanded,

the wings unspotted, the thorax golden yellow with a blackish central stripe and the segments of the abdomen have narrow, irregular, white bands at their bases.

Description of the Adult.

This is a small mosquito of slight build, the body measuring exclusive of the beak 3.5–4.5 mm.,=.14–.18 of an inch, in length. The head back of the large black eyes is covered with whitish scales, and there is a patch of black ones on each side which sometimes mix with those of the top. The proboscis is black, long and slender, 2.5–3 mm.,=.10–.12 of an inch, in length. The palpi in the female are black, the fourth joint small, oblong, with an obtuse apex and one or two long bristles; one specimen examined showed a minute fifth joint. In the male the palpi (fig. 41, 9) are black, two-thirds the length of the proboscis, the terminal two joints less than half the length of the basal joint; a few short hairs toward the apex represent the fan-like tufts. The female antennæ are brownish black, short, but with the usual number of joints; the male antennæ are dark brown, the joints ringed with white and the plumes grayish brown.

The dorsum of the thorax is covered with golden yellow scales and has a blackish central stripe which becomes diffused in the posterior portion. The pleura are dark brown, with small patches of dirty white scales. The legs are black, the femora yellowish underneath, except near the apex, the extreme apex white. The tibiæ and the first and second tarsal joints of the hind legs are white at both base and apex, the third and fourth tarsal joints white at the base only, while the last joint is wholly white. In the front and mid tarsi the bands are much reduced, the first being the only one white at both ends, the others white at the base, becoming more or less obsolete in the last two joints. The claws of the male anterior and mid tarsal joints (fig. 79, 3, 4) are unequal in size, the larger with a median and basal tooth, the smaller with a single median tooth near the base. The posterior claws (fig. 79, 5) are equal and simple. In the female the claws are equal on all feet, those of the anterior and mid tarsal joints (fig. 79, 2) one toothed, the posterior simple as in the male.

The abdomen is purplish black with whitish bands at the base of the segments, becoming broad at the sides until, beneath, it is wholly white. In the female the bands are very narrow and irregular, and are sometimes wholly wanting; in the male, however, they are broader, well defined and always present.

Habits of the Adult.

No observations have been made by any member of the force upon this species which will be almost certainly found along the shores of the Delaware River in Warren County and probably of some other streams in the rocky section of the State.

Dr. Harrison G. Dyar, who has published the life history from observations made in New Hampshire and along the banks of the Potomac, says that the adults are very troublesome on and about the river and bite freely.

Description of the Larva.

The larva with structural details is illustrated on plate figure 80. When full grown it is 7–9 mm.,=.28–.36 of an inch in length and of a pale grayish white color except the head, siphon and ninth segment. The head is rounded, almost as broad as long, blackish brown, with four rather short hairs arising from separate points in the anterior part of the vertex; a small hair tuft composed of four or five hairs is at the base of each antenna. The antenna (fig. 80, 3) is rather short, almost as broad at the tip as at the base, uniformly dark brown in color and sparsely set with small spines; the apex has one long spine, three smaller ones and the usual small peg. The hair tuft issues from the shaft slightly below the middle and consists of but two fine hairs, which do not reach the apex. The eyes occupy the part where the head is widest and are very small, consisting of a crescent shaped piece and a very small detached portion in the concavity. The whole is surrounded by a small ring of yellowish white, strongly in contrast with the dark colored head. The rotary mouth brushes (fig. 80, 4) are yellowish brown with the more central hairs pectinated at their tips. The mandible (fig. 80, 2) is normal but rather broad. The maxillary palpus (fig. 80, 6) tapers toward the apex, and has a moderate apical tuft and medium-sized, stout, basal joint. The mentum (fig. 80, 5) is broadly triangular, almost three times as broad at the base as long and with nine or ten teeth on each side, small at the apex, becoming larger toward the base.

The thorax is a little larger than the head, rounded and with slight angles at the sides, each angle giving rise to rather long hair tufts.

The abdominal segments from one to seven are greatly elongated, very disproportionate to the small thorax and comparatively large head; the lateral tufts have each three to five hairs, dimin-

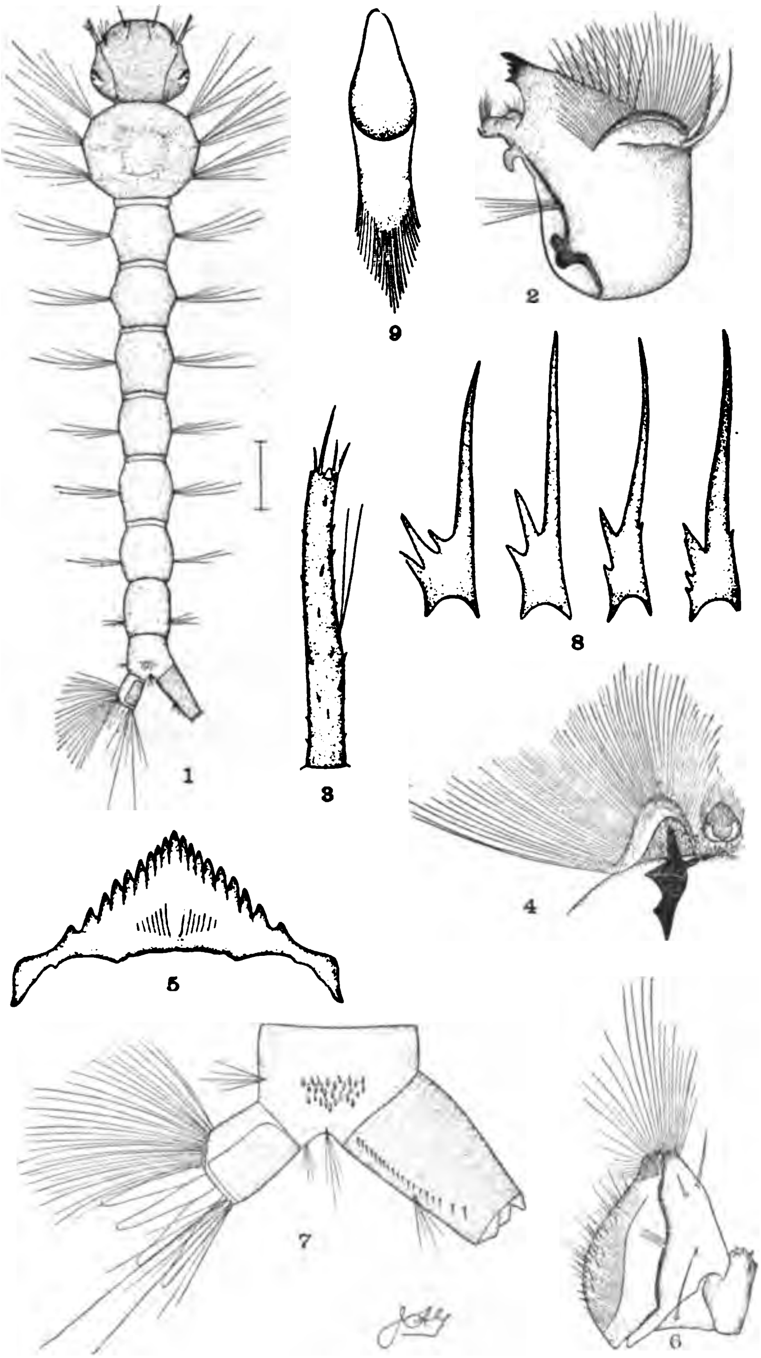

Figure 80.

Culex atropalpus: 1, larva; 2, mandible; 3, antenna; 4, mouth brush; 5, mentum; 6 maxillary palpus; 7, terminal segments and siphon; 8, siphonal spines showing variation; 9, a single scale from 8th segment: all enlarged. (Original.)

ishing in size posteriorly, the seventh with small hair tufts only. The eighth segment has lateral patches of scales, from twenty-five to thirty-five in each patch; the single scales very small, rather broad and with fine, long fringes confined to the broad apex. The anal siphon is dark brown, about twice as broad as long and evenly tapered toward the apex. The double row of spines extends almost to the apex and consists of seventeen to twenty-one each, the individual spines broad at the base, with two or three large teeth and sometimes a small one on the opposite side as shown in figure 8. The siphonal tuft is situated in the center of the siphon, slightly nearer the apex and this is the only species where the spines exceed the tuft; usually it terminates the row. The ninth segment is very small, the dorsal half saddled by a dark brown chitinized plate; the ventral brush is moderate and usually confined to the barred area, though rarely small tufts are below it; the double dorsal tuft is normal, each with one long hair. The anal gills are slender, a little longer than the ninth segment.

Habits of the Early Stages.

According to Dyar the eggs in fall are laid in patches on the rock side of the pot holes where the larvæ occur, usually at a time when the water is low, and the winter is passed in that condition. They begin to hatch in March, but irregularly, and the larvæ grow slowly. From adults matured late in April eggs were obtained after two weeks and these were scattered loosely over the surface of the water, not adherent to the sides, in patches. The eggs are black, elliptical, the ends round pointed, coarsely reticulated. Those laid in spring hatched in three days and there are, probably, several broods during the season. I have had under observation only one lot of the larvæ brought down from Islesboro, Maine, by my young son, and these agreed so well in habit with what Dyar says of them that I can do no better than quote: "The larvæ are rather deliberate in their motions and habitually remain long below the water. They can be seen browsing along the sides of the jar well below the surface; feeding on the green *Protococcus* that grows there. Occasionally they rise and push the breathing tube through the surface film for a few seconds, but they do not remain hanging there, but shortly descend to resume browsing. The anal processes are long and well supplied with trachæ, which permits the larvæ to remain long under water."

CULEX CANADENSIS, THEOB.

The Woodland pool Mosquito.

The distinctive characters of this species are the white banded tarsi, the last joints of the hind pair being entirely white and the joints being white at both base and tip; the black, unbanded beak, the brown, unbanded thorax, unspotted wings and the medium or rather large size. This combination of characters holds equally for both sexes and separates *canadensis* from all other New Jersey mosquitoes.

Description of the Adult.

This is a mosquito of medium size and not very robust in appearance. The body, exclusive of the beak, is about 6 mm., or one-quarter of an inch in length; the beak is about one-third the length of the body and the wings expand 10 mm., or about three-eighths of an inch. The head is brown, largely taken up by the black eyes; the beak is black or blackish, without marks or rings; the palpi in the female (fig. 81, 3) short, blackish, four-jointed, set with rather stout and moderately long hair, the terminal joint very small, yet not retracted nor shrunken. In the male the palpi (figs. 41, 2) are as long as the beak, black, the basal joint with two white bands, the second and third joint also incompletely banded at base. Toward the tip the palpi have dense, fan-shaped tufts of hair inwardly.

The antenna of the male is plumose, silky brown in color, not much more than half as long as the palpi, the terminal two joints (fig. 5, 1), long and slender, the central and basal joints (fig. 5, 2) cup-shaped, with a circle of very long silky hair. In the female the antenna (fig. 5, 3) is longer, much more slender, the individual joints (fig. 5, 4) set with shorter and longer stiff hair and with a circle of long, moderately stout hair at the base of each joint.

The thorax is evenly brown without obvious lines or spiny clothing. The legs are black or blackish, the femora yellowish on the inside, a white dot at the knee. Tibiæ set with small spines and some longer whitish hair, white at the tips. All the tarsi are white ringed, the base and tip of each joint being white. In the anterior tarsi there is only one well marked ring in the female, the others being much reduced, in the male all the rings are almost obsolete. The mid tarsi have all the rings obvious, but much reduced toward tip. The posterior tarsi have all the joints broadly

white ringed, and the last joint is entirely white. In the male the claw joint of the anterior tarsi (fig. 81, 7) is inwardly excavated

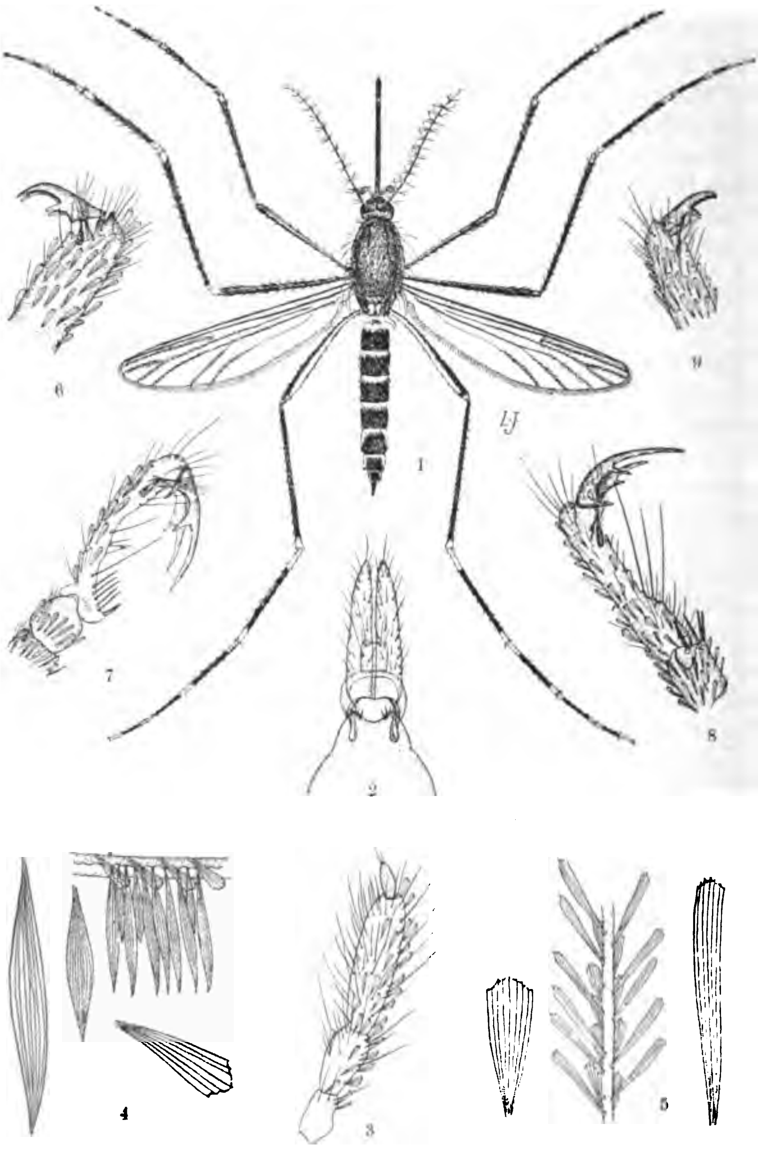

Figure 81.

Culex canadensis: 1, female adult; 2, the ovipositor; 3, the palpus; 4, margin of the wing showing the fringe scales; 5, part of vein showing scales; 6, anterior claws of female; 7, anterior, 8, middle, and 9, posterior claws of male: all much enlarged. (Original.)

and set with spurs and spines, the inner claw is larger, with an acute tooth at base and another near middle, the outer claw is smaller and has only the median tooth. The claw joint of the mid tarsi is more normal in shape, yet a little excavated on the inner side; the claws are similar to those of the anterior tarsi, but are smaller (fig. 81, 8). On the posterior tarsi the claw joint is normal and the claws (fig. 81, 9) are small, similar, with a median tooth. In the female the tarsal claws are all alike (fig. 81, 6), small, with a single tooth before the middle.

The abdomen is black or blackish above, with narrow white bands at base, the sides becoming more broadly white until, beneath, it is white with broad black bands. The amount of white on the upper side is variable, but in fresh specimens the basal bands are usually distinct. In the male the abdominal segments are better defined, the white bands are more clearly marked, expanding at the sides, and the surface is covered with fine, long, divergent hair.

The range of variation is small, there is a considerable difference in size as with others and some in the intensity of the body color. The apparent variation in the distinctness of the white abdominal bands is usually due to the age of the specimen, all fresh examples showing clear contrasts.

Description of the Larva.

The larva and its parts are illustrated on plate 82, and the references are to the figures on that plate. The full-grown wriggler (fig. 1) measures from 7–8 mm.,=.28–.32 inch, excluding the anal siphon; is rather stout in build, very active and usually dirty slate gray in color, except the head, which is usually black. There is little variation in the color of the mature larva, but in the earlier stages it is lighter and the head seems darker in contrast. Up to the time when it is two-thirds grown, there is usually a pale band or neck which gives rather a characteristic appearance and usually identifies the larva. The head is one and one-half times as wide as long and varies in color from yellowish to a deep blackish brown. In the small larvæ the head is black or nearly so, except after a recent moult, when it is yellow or whitish and proportionately much larger; sometimes this pale color persists and detracts so much from the usual appearance that it gives the impression of a different species. The maculation on the vertex which is shown in the figure is very constant and does not vary from the definite pattern shown. The marks and dots

are never very prominent and the darker the general color of the head, the less obvious they appear; but usually they can be made out. There are four tufts of four or five hairs each on the head, two on each side of the centre, one pair a little ahead of the other and a larger tuft is at the base of each antenna. The antenna is short and slender (fig. 4), light brown in color, paler at the base, set with sparse stout spines and with more numerous very small ones. Viewed from the side the antenna is slightly bi-sinuate, *i. e.*, it makes both an in and out curve on each margin. The tuft is composed of from six to ten long hairs and is situated well below the middle. The apex is a long and short spine, two bristles and a little joint, all articulated to the main segment. The eyes are black, of good size, somewhat kidney-shaped, and occupy the widest part of the head. The central hairs of the rotary mouth brushes are very finely comb-toothed or pectinated. The mentum (fig. 6) is very constant, triangular in form, with from twelve to fourteen teeth on each side of the apex, the toothed edges only slightly curved. The mandible (fig. 5) is characteristic in form and best described by a reference to the figure. The maxillary part bearing the palpus has a large tuft of moderately long hair and its inner surface is well clothed with hair arranged in rows and patches. The thorax is angulated at the sides, one and one-half times as broad as long, the dorsum a little depressed and wrinkled, each of the three lateral angles with a tuft of long hair arising from a tubercle, and two tufts of two hairs each, at the anterior margin. Abdominal segments one to seven are oblong or sub-quadrate in form, each with a lateral hair tuft which becomes smaller and shorter posteriorly. The eighth segment has lateral patches of from twenty-five to fifty elongated fringed scales (fig. 8), forty being the average number, arranged as shown in figure 7. These scales are approximately constant in all stages, but are fewer in number and differently arranged in the smaller larvæ. The anal siphon is at least three times as long as broad (fig. 7), and has two series of toothed spines (fig. 9), each series ranging from sixteen to twenty-four in number, eighteen being about average. In the mature larva the color is like that of the body, but in the early stages the tip is black. The ninth segment is sub-quadrate in outline, the dorsal part of apical margin with two tufts in each, of which one hair is much longer than the others; the ventral part of the margin with a barred area from which arise ten to twelve tufts of from five to seven hairs each. The anal gills are moderately long and not supplied with obvious trachea in the later stages.

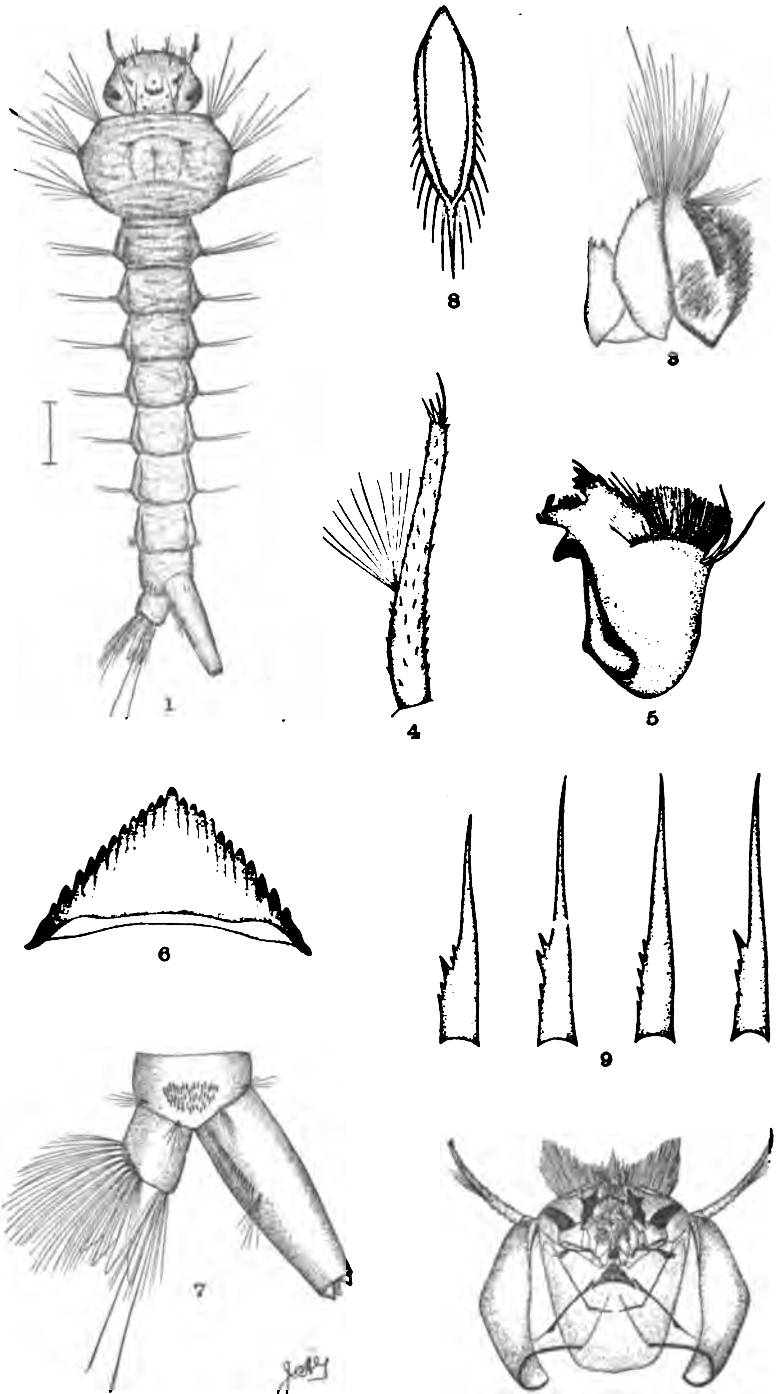

Figure 82.

Culex canadensis: 1, larva; 2, its head from beneath; 3, maxillary palpus; 4, antenna; 5, mandible; 6, mentum; 7, terminal segments and siphon; 8, a single scale of 8th segment; 9, siphonal spines showing variation: all much enlarged. (Original.)

The young larva in captivity, when undisturbed, has the habit of using the anal siphon as a pivot around which it swings with head bent upward so as to feed on material just below or at the surface. In all stages the larva is more nearly parallel to the surface than most other species.

Habits of the Early Stages.

This is the earliest and latest of the species that winter in the egg stage: earliest as to both adult and larva, and latest as to larva only. The extreme records for either direction are from Mr. J. Turner Brakeley, who found recently hatched larvæ in November and again in the February following. That the February larvæ did not hibernate as such is abundantly proved by the almost daily collections made during February, 1903, by the fact that larvæ developed in water with a portion of the mud bottom from woodland pools and, finally, by the fact that I found the eggs in some samples of mud from the bottom of breeding pools sent in to me for examination at my request.

The first find was made February 6th in a jar in which larvæ of *C. melanurus* were being bred. These larvæ were collected February 3d, and at that time no trace of small wrigglers was noted. One example found on the 6th seemed as if it had just hatched, and there is no reasonable doubt that the transfer from the breeding pools to the house temperature induced development. Collections were made in the field February 8th in a sleet storm, the pools ice covered and the water temperature 36 degrees. Twenty-five specimens, all of them apparently just out of the egg, were collected, and these mostly out of the bottom mud where they seemed to be in hiding. To test this yet further, a supply of bottom material was secured February 9th, and in less than twenty-four hours minute larvæ were found in each of the breeding jars into which it was placed. It is positively proved, therefore, that during the early days of February, in water just above the freezing temperature, the larvæ of *canadensis* may and do hatch from the egg under entirely natural conditions. Hatching may be hastened by disturbing the material in which the eggs are laid, and this probably accounts for the larvæ first found in the jars.

February, 1903, was a cold month and the breeding pools in which the larvæ were found became iced over several times, so as to bar absolutely all access to the surface; nevertheless, there was no apparent decrease in the number of specimens, but, on the contrary, a continuous increase. Artificial tests were made

February 18th and 19th, when the bottles with baby larvæ were allowed to freeze almost solid. Nevertheless they survived the test and specimens could be watched partly imbedded in ice, wriggling to free themselves until the surrounding temperature rose sufficiently to release the ice grip. In nature the larvæ usually manage to escape actual freezing by getting into the bottom mud, and that was illustrated by an examination made March 2d, after a night when the thermometer registered 23 degrees. The pool was completely ice-covered, a hole was chopped near the edge with an ax, and through this hole larvæ were dipped up in fair numbers with the bottom material. No larvæ were imbedded in the ice.

Development at this season is slow and the new hatchings during early March rapidly overhauled those that appeared earlier, so that by the middle of that month the great bulk of the brood was about half grown or a little larger. The pupal period ranges from two to seven days, according to temperature.

The earliest record for adults taken outdoors is April 14th and is also from Mr. Brakeley. It is not until the early days of May, however, that both sexes are at all abundant, and at that time not all of the hibernated eggs are yet hatched. There is a false appearance of a second brood coming immediately after the first adults are on the wing; but it seems fairly certain that all the *canadensis* that are found until the middle of June are from hibernating eggs. After that time the species decreases in number, though it has been taken in all stages throughout the summer. What seems to be the second brood begins to hatch during the early days of June, and thereafter I have not been able to identify any definite period when young were present in large numbers.

Our records show larvæ, pupæ and adults at South Orange as early as April 27th, and at Garret Mountain, Paterson, April 29th. A month later, May 28th, South Orange again had recently hatched larvæ in considerable number. From the Paterson district larvæ were taken that matured early in September, and larvæ found in the Great Piece meadows in early September yielded *canadensis* up to the 21st of that month. Perhaps the greatest abundance of *canadensis* is in late May, and thereafter a constant decrease. It occurs throughout the State.

The egg is black, spindle-shaped, smooth, rather thicker than that of *sollicitans*. When the top has been lifted off to admit the egress of the larva, it looks like a stubby, half smoked cigar. This egg may be laid either on the water, through which it sinks to the bottom at the edge of a pool, or on the moist ground of

depressed spots. I have no direct observations on this point, but the places where the eggs and larvæ have been found leave no other explanation. It is, at all events, certain that the eggs are in the mud at the bottom of pools early in spring.

Breeding places are any sort of woodland pools or even larger water bodies. Mr. Brakeley finds them in the water covering his cranberry bogs during the winter, sometimes in very large numbers. These bogs are covered with water late in fall and are kept covered until the middle of May thereafter, just long enough to mature *canadensis*. From that time until late October the bogs are dry, and when they are flooded *canadensis* adults have disappeared. The eggs must, therefore, have been laid on the bogs when they were dry, to account for the swarms of larvæ found in early May. It should be noted that these bogs are closely surrounded by woodland.

I have never found the larva in open swamps or in pools far from the edge of a wood, but it was present once in a pool with *cantator* at the edge of the Shrewsbury meadow.

Our records show collections made in most of the counties of the State, and there is probably not a bit of moist woodland anywhere in it in which *C. canadensis* may not be found in early spring.

The wrigglers that have been found associated with *canadensis* are *C. cantans*, which is usually rare, but common in some seasons; *C. aurifer*, which is local and rare; *C. melanurus*, which is yet more rare; *C. territans*, which often replaces it late in the season; *C. reptans*, *C. serratus*, *C. trivittatus*, *C. dupreei* and *C. squamiger*, all of which are rare.

Though the larvæ may be found in all sorts of pools, they are commonly of clean water. Woodland springs nearly always have some of them, and the pools in which they are most plentiful are those formed by melted snows and early spring rains over a bed of dead leaves in a depression or choked stream bed near the edge of the woodland, or in a small clearing. I have never found them in really foul water.

As nearly as can be made out from field observations, all *canadensis* eggs that hibernate hatch between February 1st and May 10th, at the latter of which periods adults of the earlier hatching are already out in full force and ready to oviposit. Of the eggs laid during May a fair percentage hatch early in June and give a fair second brood of adults. When these adults oviposit, an equal percentage of their eggs also develops, and this continues through the season, the bulk of each batch of eggs lying over to the next year. This keeps up an ever decreasing supply as

the season advances, and yet provides liberally for the enormous spring crop in spite of the dangers attendant upon so long a quiescent period under varying climatic conditions. This accounts for the November larvæ found by Mr. Brakeley, as probable progeny of adults which matured in late September or early October. It is assumed here that the larvæ that hatch so late in the season do not reach maturity.

Habits of the Adult.

This is esentially a woods mosquito. It bites hard when it gets a chance and readily attacks those that venture into its domain, but it is easily scared off and never follows into the open. Nor does it get into houses or even on porches, except where a house is practically in the woods. It is almost never found in cities, towns or villages, so, though it is really one of our common species, it is not to be accounted a very troublesome one.

During the day it is not readily started, except in the darker woods; but in the early morning and at dusk it flies readily and may get for a short distance away from its normal shelters. It is not in any sense a migrant, however, and under ordinary circumstances the adults probably never get many yards away from the place where they hatched. The males live only a few days; the females seem to remain for several weeks.

CULEX TRISERIATUS, SAY.

The Tree-hole Mosquito.

A small or medium sized mosquito, with black, unbanded legs and beak; the sides of the thorax silvery white, grayish on the dorsum, leaving a well-defined central stripe, which becomes wide posteriorly. The abdomen is black, with white lateral marks, encroaching upon the dorsal part at the bases of the apical two or three segments. The patches on the sides of the thorax are larger and whiter than in any other species.

Description of the Adult.

This mosquito varies considerably in size, ranging from 4 to 6 mm., = .16–.24 of an inch in length, excluding the proboscis, which is 2–2.5 long. The occiput is almost entirely covered with

grayish white scales; the proboscis is black, without marks or rings; the palpi in the female are normal, dark brown or blackish, with the terminal joint very small, bluntly pointed at the apex and flat at the base. In the male the palpi (fig. 41, 8) are black, slightly dilated toward the apex, with steel blue reflections; the basal joint long and slender, the central short, and together they

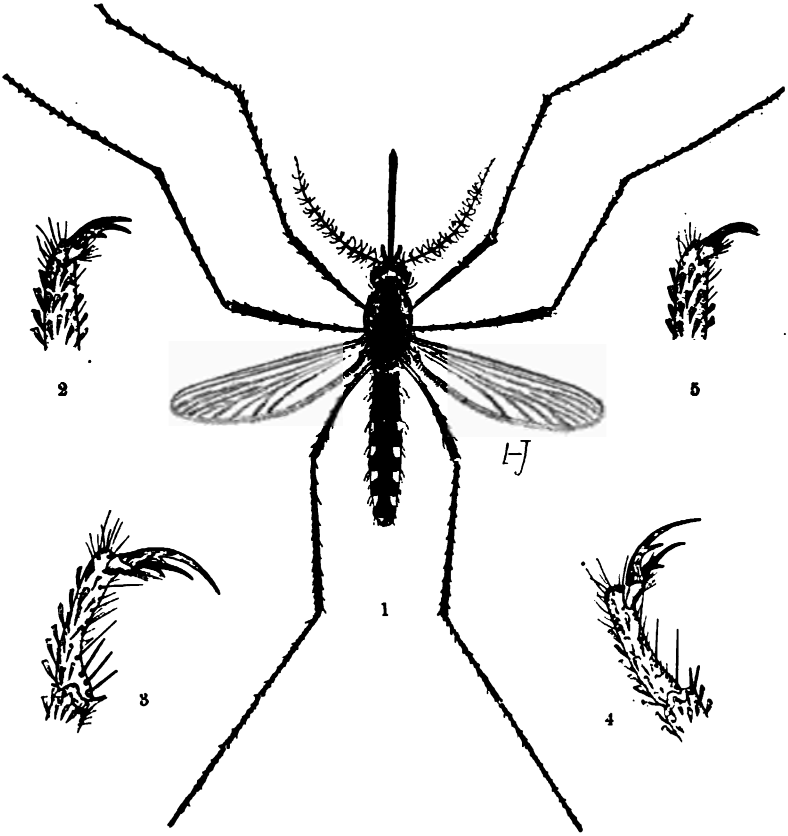

Figure 83.

Culex triseriatus: 1, female adult; 2, her anterior claws; 3, anterior; 4, middle, and 5, posterior claws of male: all enlarged. (Original.)

reach the tip of the proboscis. The terminal joint is very short, only a little longer than half the length of the central. The fan-like tufts are small and scant. The antennæ of both sexes are brown, with the plumes of the male paler.

The dorsum of the thorax is grayish white and has a broad black band in the center, becoming wide and rounded posteriorly.

The pleura are chestnut brown, almost covered with patches of silvery white scales. The femora are black, yellowish beneath and with a whitish spot at the knee; the tibiæ are black, paler beneath and the tarsi are wholly black. The claws of the male anterior and mid tarsal joints (fig. 83, 3 and 4) are unequal in size, the larger evenly curved, with a single median tooth, and the smaller almost straight with a median tooth slightly nearer the base; the claws of the posterior tarsal joints are equal and simple. The claws of the female are equal on all feet; those of the anterior and mid tarsal joints single toothed, the posterior simple like the male.

The abdomen is black, with brown hairs on the apical margin of the anterior segments, extending backward over those following. Beneath it is creamy white, with pure white basal marks extending up the sides and coming well upon the dorsal surface in the posterior segments; the apical segment yellowish. In the male the white marks sometimes cross the abdomen as narrow basal bands.

Habits of the Adult.

This is rather a handsome species and one that is rarely found outside of woodland or its immediate vicinity. It occurs throughout the State, records of captures of adult or early stages coming from Lahaway, in Ocean County; New Brunswick, in Middlesex County; the Great Piece meadows, Chester and Lake Hopatcong, in Morris County, and the environs of Newark, in Essex County. There is no reasonable doubt but that the species occurs throughout the State.

It is one of the species that winters in the egg stage, either under water or in a place where water is likely to come in early spring. The adult lays its eggs as near to the surface of the water as possible, at the very edge of the vessel or cavity selected for a breeding place, and these eggs hatch, after a suitable period for development, when they become covered with water.

The earliest date that I have for adults is June 1st, when the species was the common form found on the dams around the cranberry meadows at Lahaway, and from that date until October adults were taken in some part of the State. Practically all of the collectors took *triseriatus* in some stage, hence, though it is by no means a common mosquito, it is at least easily captured by the careful collector.

There is no record that the species has been at any time taken indoors under any circumstances; but there is a clean record of its occurrence on porches of houses closely surrounded by trees.

The species bites readily and hard, but the records as to results differ. The collectors at New Brunswick make light of the bite, while Mr. Brakeley, mosquito seasoned as he is, records the fact that it raised "welts" on him at Bordentown.

This species is no traveler, and there is every reason to believe that it does not move farther from its place of birth than is necessary to find a place for oviposition. It does not fly normally until evening, yet it is easily disturbed, and practically all the adults taken were captured during the day. In no instance was this form included in the captures made after dark.

There is practically no record that in New Jersey this species is at any time entitled to consideration as a pest. Its occurrence even when most abundant would hardly attract attention.

Description of the Larva.

The larva, plate figure 84, 1, is long and slender, averaging 8 mm.,=.32 of an inch in length, though specimens are sometimes as long as 10 mm. In color it is brownish or grayish with the head and siphon darker or blackish; young and half grown larvæ are grayish white. The head is broader than long, yellowish to dark brown in color, with scarcely any darker shading. There are four small hair tufts of five or six hairs each on the anterior part of the vertex, and two long setæ are slightly to the rear of them; another small tuft is at the base of each antenna. The antenna (fig. 81, 5) is long, almost straight, dark brown in color, blackish toward the base and without spines or hairs over the surface. A single long seta arises from a scarcely perceptible offset at about the middle, and the apex is one long spine, two shorter ones and a little articulated peg. The eyes are black, comparatively small and are divided into two parts; a large crescent shaped piece and a very small one in the concavity; they are sometimes encircled by a broad white ring. The rotary mouth brushes are yellow, pectinated at the tips of the more central hairs. The mentum is triangular with ten or eleven teeth on each side of the apex, which become larger toward the base; but there is considerable variation, chiefly in the curve of the sides, as is shown in figure 4. The mandible (fig. 84, 2) is normal with small spines scattered near the base. The maxillary palpus (fig. 84, 3) is short and chunky, with a small apical tuft and large basal joint.

The thorax is broader than long, slightly angulated at the sides. There are six rather short lateral tufts, two smaller on the anterior margin and two very small ones on the dorsum, near

the anterior margin. The abdominal segments are subquadrate in the anterior part, becoming elongated posteriorly up to segment 7, and giving the larva a very disproportionate appearance. Each segment has four short hair tufts on the dorsal surface and several others at the sides, in addition to the long lateral hairs. These have four or five hairs on each tuft on the anterior two segments, two each on the following up to segment 6; the seventh with the small tufts only. At the time the drawing was made none of the specimens in hand retained the long lateral hairs of segments 3 to 6, inclusive; since then, however, large numbers of larva were received, so the correction is made in this description. The eighth segment is very short, with eight to thirteen scales arranged in a single irregular row on each side. The individual scale (fig. 84, 8) is much elongated, with a fringing of short hair at the sides and apex. The anal siphon (fig. 84, 6) is dark brown, short and stubby, with a double row of spines, from fifteen to twenty-one in each row; small teeth extend upward from the base of the individual spines. A hair tuft composed of but two hairs terminates each row. The ninth segment is about as wide as long, with a saddle the same color as the siphon. The ventral brush is moderate in size and consists of eight or ten tufts of four or five hairs each; the dorsal tufts have each one very long hair. The anal gills are short, about the same length as the ninth segment.

Habits of the Early Stages.

This is an unusually long, slender wriggler and easily recognizable by that character as well as the contrasting dark head and tail. It is rather deliberate in its movements, usually, and has little of the jerky wriggling that fits the proper name to mosquito larvæ in general. It has also the habit of forming a loop or circle, bringing its head almost or quite into contact with the anal siphon and then allowing itself to sink slowly to the bottom. In a jar containing a number of the larvæ this habit may be observed at almost any time. Some other species of *Culex* do this occasionally; but with *triseriatus* it seems to be a fixed habit. So, the wriggler seems to be able to remain below the surface for quite a long time, sometimes lying quiet, sometimes feeding among the bottom fragments.

The earliest record for the larva is May 9th, 1903, when Mr. Grossbeck took very small to one-third grown specimens on the Garret Mountain near Paterson from a water-filled cavity of a hollow tree. July 4th, Mr. Brehme found them in a similar place

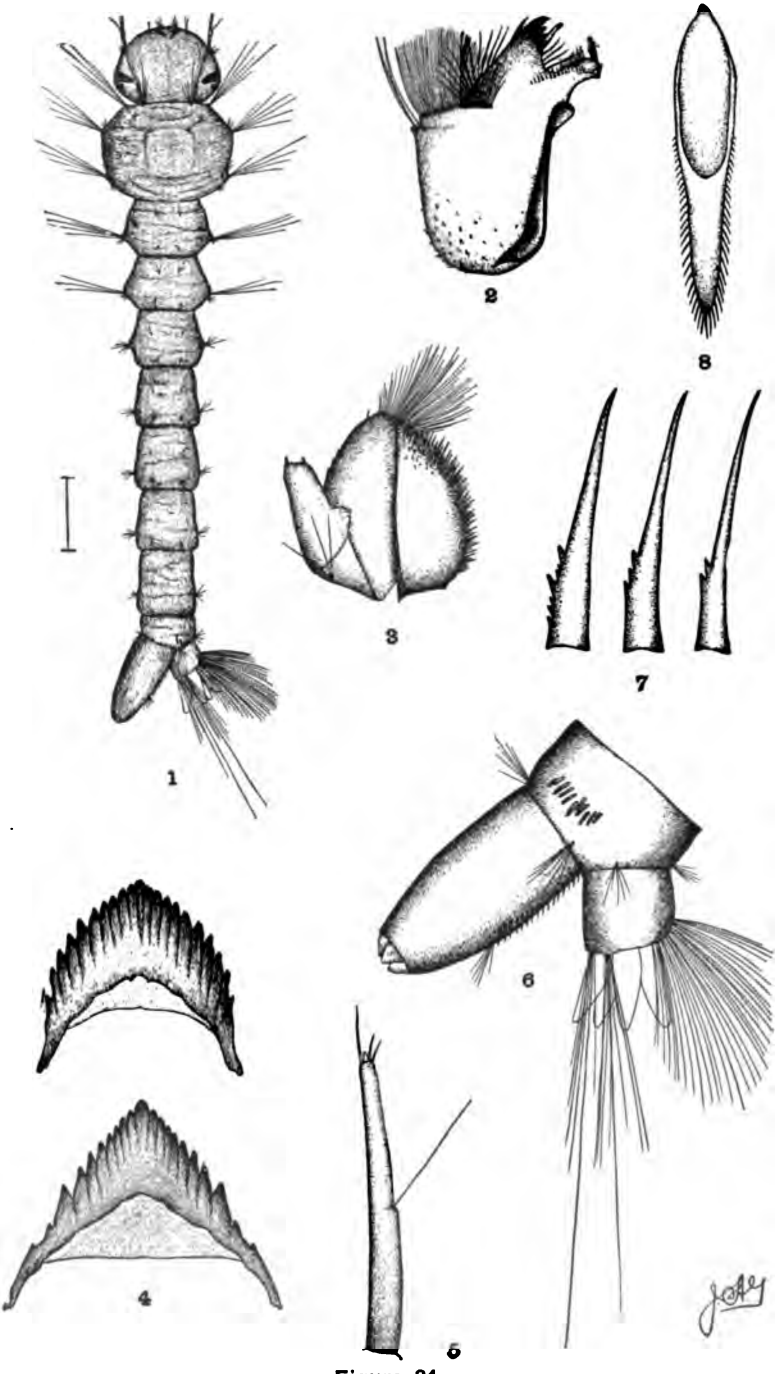

Figure 84.

Culex triseriatus: 1, larva; 2, mandible; 3, maxillary palpus; 4, variations of mentum; 5, antenna; 6, terminal segments and siphon; 7, siphonal spines; 8, a single scale of 8th segment: all enlarged. (Original.)

in Clinton Township. July 12th, Mr. Dickerson took larvæ and pupæ from holes at the base of trees at Chester, where Mr. Harold O. Marsh also found them August 21st. At the same point where he first found them in May, Mr. Grossbeck took larvæ and pupæ July 15th, and at that date there were full grown larvæ and pupæ as well as very small examples, recently hatched; an incoming and an outgoing brood. The last collections were made by Mr. Brehme, September 3d, in the Great Piece Meadows, well advanced larvæ and pupæ being found.

It will be noted that all these collections were made in holes in trees and stumps, and such cavities when water filled are, without doubt, the normal breeding places for this species. Mr. Dickerson took a few examples at New Brunswick in a little woodland brook broken into disconnected pools during the summer, and I took a full brood from an iron kettle that had been half buried in sand, was partly filled with chips, and almost hidden in the grass at Lahaway. These are the only records of finding them elsewhere than in tree cavities.

Mr. Brakeley, by the bye, who originally found that there were larvæ in this iron kettle, replanted it and in fall found the eggs along the sides at or above the then surface of the water. These eggs were kept water covered during the winter by Dr. Dyar, to whom they were sent, and hatched at Washington, May 18th.

This larva, in appearance, is nearer like that of *Stegomyia fasciata,* the yellow fever mosquito, than any other of those that occur in New Jersey. Whether this indicates a closer relationship than the adults seem to show and, whether at a pinch, *triseriatus* might do the work of *fasciata* in transmitting the yellow fever, are interesting speculations.

Development is slow, especially when the larvæ are removed from the water in which they lived; in fact unless they are nearly full grown they rarely develop at all. The pupal period ranges, even in midsummer, from four to seven days.

Meanwhile, though this mosquito is occasionally present locally and bites when it gets a chance, its existence can scarcely be seriously annoying anywhere.

CULEX SERRATUS, THEOB.

The Silver Striped Mosquito.

A moderate sized black mosquito, characterized by a broad silvery gray stripe through the center of the thorax. The legs and beak are unbanded, the wings unspotted, while the abdomen

is black, with lateral white marks which partly show on the dorsum of the apical segments.

Description of the Adult.

This is a mosquito of ordinary build, measuring 5–6 mm. = .20–.24 of an inch in length, exclusive of the beak. The head is brown, with a large patch of white scales in the center of the occiput extending between the eyes, to which there is a faint whitish border on the posterior margin. The proboscis is black throughout, one-third the length of the body, or about 2 mm. long. The female palpus is normal in form, black, the terminal joint obsolete; in the male it is black, shape and fans as in *C. cana-*

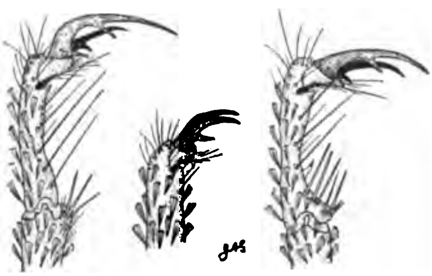

Figure 85.

Culex serratus: 1, anterior; 2, middle, and 3, posterior claws of male: enlarged. (Original.)

densis, longer than the proboscis by the last joint. The antennæ in both sexes are very dark brown, the basal joint in the female yellowish, the plumes in the male light brown.

The thorax is black, with a longitudinal silvery gray stripe in the center of the dorsum, which narrows somewhat toward the front, has sharply defined edges and does not quite reach the anterior margin. The pleura are light brown, becoming very pale beneath, and have small patches of white scales. The legs are black, with deep blue reflections, the under sides of the tibiæ yellowish, while on the femora they are creamy white. The claws of the male anterior and mid tarsal joints (fig. 85, 1 and 2) are unequal in length, the larger with a median and basal tooth, the smaller with a single tooth near the base. On the posterior tarsal joint (fig. 85, 3) the claws are equal, each with a single tooth a short distance from the base. In the female the claws are alike

on all feet, equal in size and, like the posterior ones of the male, have a single tooth near the base.

The abdomen is black above, with purplish reflections, pale yellow beneath, the segments marked with lateral white spots extending upon the dorsal surface at the front angles of the apical segments.

Habits of the Adult.

This is distinctly a handsome species, readily recognized by the broad silvery stripe on the back. It was originally described from South America, but occurs throughout New Jersey, though nowhere in large numbers. The earliest record is near Livingston Park, New Brunswick, June 23d, when one example was taken in company with eighteen *canadensis* and seven *squamiger,* all in attempting to bite. Several times, later in the season, specimens were taken in this wood and, except for some examples taken at Cape May by Mr. Viereck, there were no other adults captured. Little is positively known, therefore, of the habits of the adults and that little is not especially to its discredit. It bites, of course, when its haunts are invaded, but it lives in low swampy woods where rubber boots are desirable if not necessary at most periods and where few persons ever go. There is absolutely no record of its capture in towns or houses, hence it cannot be included among the pestiferous forms.

Description of the Larva.

The larva is figured on plate 86 with details of structure. It is a very robust wriggler and when full grown is 6–7 mm. = .24–.28 of an inch in length, excluding the anal siphon. The head is dark brown in color, with darker diffused blotches on the vertex, widest at the eyes, tapering anteriorly and somewhat flattened in front. Four hairs are on the anterior part of the vertex, each arising from separate pits, one pair in advance of the other, and there is a tuft of five or six hairs at the base of each antenna. The antenna (fig. 86, 4) is short, not quite half the length of the head, thickest at the basal third and terminated by one long spine, three smaller ones and a small joint. A hair tuft of moderate length issues from the shaft at about the middle, and the surface is set with small, stout spines. The rotary mouth brushes have simple and pectinated hairs, the pectinated ones short and curved in the more central part and obscured by the long simple ones. The mentum (fig. 86, 7) is triangular, with fifteen or sixteen

small teeth on each side of the apex. The mandible (fig. 86, 5) is normal and the maxillary palpus is short and broad, with a moderate apical hair tuft and rather a large chunky, basal joint. There are patches of hair on the surface of the palpus and some of these hairs are feathered.

The thorax is angular, wider than long, with moderate hair tufts at each of the lateral angles and two smaller tufts on the anterior margin. It is white in color, with a median black portion becoming wide anteriorly.

The abdominal segments 1 to 6 are almost black, the anterior two with lateral tufts of four or five hairs each, the following ones with two hairs to each lateral tuft, diminishing in length posteriorly. The seventh and eighth segments are white, with short tufts only; the eighth with a regular row of five or six scales on each side; the individual scales shaped as in figure 86, 9. The anal siphon is dark brown, almost black, about twice as long as broad, slightly dilated near the base, the valves also a little dilated so as to flare at the tip. The two rows of spines consist of five or six each, the single spines not curved, essentially like figure 86, 10, though there is some variation. The ninth segment is a little longer than broad, the same color as the siphon. The ventral brush is moderate, with a few small tufts below the barred area. The double dorsal tuft is short, each part with one very long hair. The anal gills are long and slender, tapering to a point, and are without obvious tracheæ.

Habits of the Early Stages.

The suggestion that the species winters in the egg stage is made because it appears constantly associated with *canadensis* and *sylvestris,* of which this is true. No very early collections have been made in the Livingston Park woods, hence it is impossible to say whether the adults taken June 23d were the first of the year, or whether there had been an earlier brood. In collections made July 2d young larvæ of *canadensis* were found; but the season of 1904 was not a favorable one for woodland pools and there was no such abundance of wrigglers as occurred in 1903.

The earliest actual date is July 29, 1903, when Mr. Van Duersen collected full grown larvæ and pupæ. From the pupæ 6 males and 4 females emerged July 30th, and 5 females August 1st. Some of the larvæ pupated July 31st and adults emerged August 3d, a period of three days. August 13th of the same year another collection was made and half-grown larvæ were found with full-grown examples and pupæ. In 1904 half-

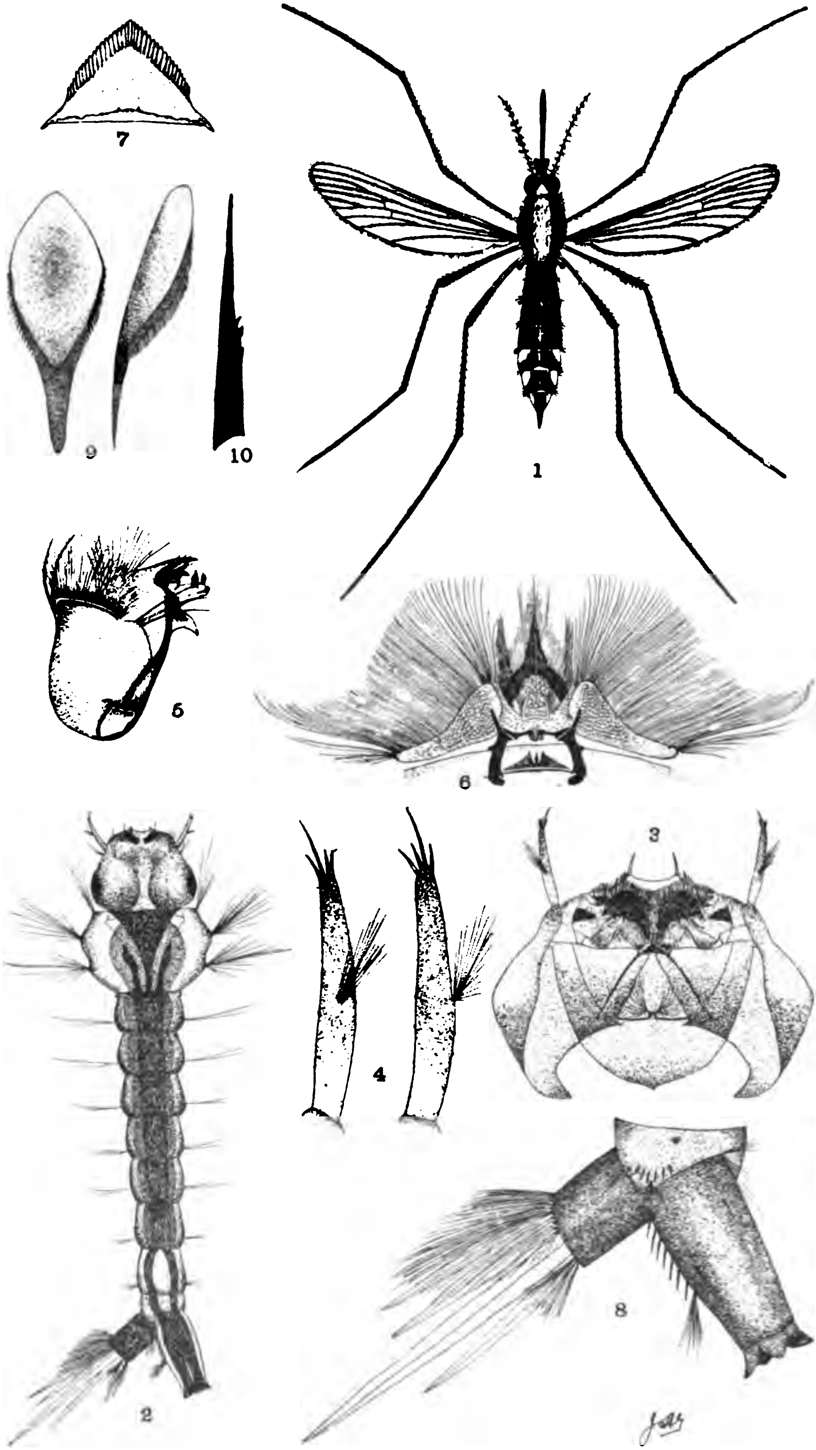

Figure 86.

Culex serratus: 1, female adult; 2, larva; 3, its head from beneath; 4, the antenna; 5, mandible; 6, mouth brushes; 7, mentum; 8, terminal segments with anal siphon; 9, scales of 8th segment from below and side; 10, a siphonal spine: all enlarged. (Original.)

grown larvæ were found August 9th by Mr. J. H. Voorhees, and on the 15th mature larvæ and pupæ were taken. September 3, 1903, a few more partly grown larvæ were found at Livingston Park by Mr. Van Duersen, and on the 9th Mr. Grossbeck found a few nearly full grown larvæ in a woodland pool in the Great Piece Meadow, from which adults were obtained September 17th and 21st. The latest collections were made September 30th at Livingston Park, and adults from this lot were all out before the middle of October.

From this record a continuous breeding is indicated, the number of existing pools determining the number of broods. Though there was an abundance of rain near New Brunswick during the summer, the woods were, nevertheless, unusually dry, a result of the very severe, continuous winter which kept moisture out of the ground and allowed the water to run off or to evaporate in the spring before the surface was in an absorbent condition. The result was that when rains did come they were completely absorbed and not enough was in the ground at any time to allow standing surface pools.

CULEX DUPREEI, COQ.

Dupree's Mosquito.

Resembles *C. serratus* on a small scale; the silvery dorsal stripe is well defined and becomes wide posteriorly in the female; but in the male it is diffused. The beak and legs are unbanded and the wings unspotted, while the abdomen is white-marked laterally, showing slightly on the upper side at the basal angles of the posterior segments.

Description of the Adult.

This is a small blackish mosquito, the body measuring 2 to 3 mm.,=.8 to .12 of an inch in length, exclusive of the beak, which is about 1.5 mm. long. The occiput of the head is covered with silvery white scales and there is a black patch on each side which sometimes mixes with the scales of the occiput. The proboscis is uniformly blackish, and the palpi in the female are normal, dark brown, with the terminal joint extremely small, circular in outline and covered with fine short hairs. The male palpi are brown, shaped like those of *C. canadensis*, save that the first joint is dilated a little at the base and again one-third

from the base; it is nearly as long as the proboscis. The antennæ are brown in both sexes, black at the base in the female.

The thorax is deep brown, with a silvery white median stripe, which becomes wide posteriorly. In the female this stripe is well defined and sometimes rather broad; but in the male it is

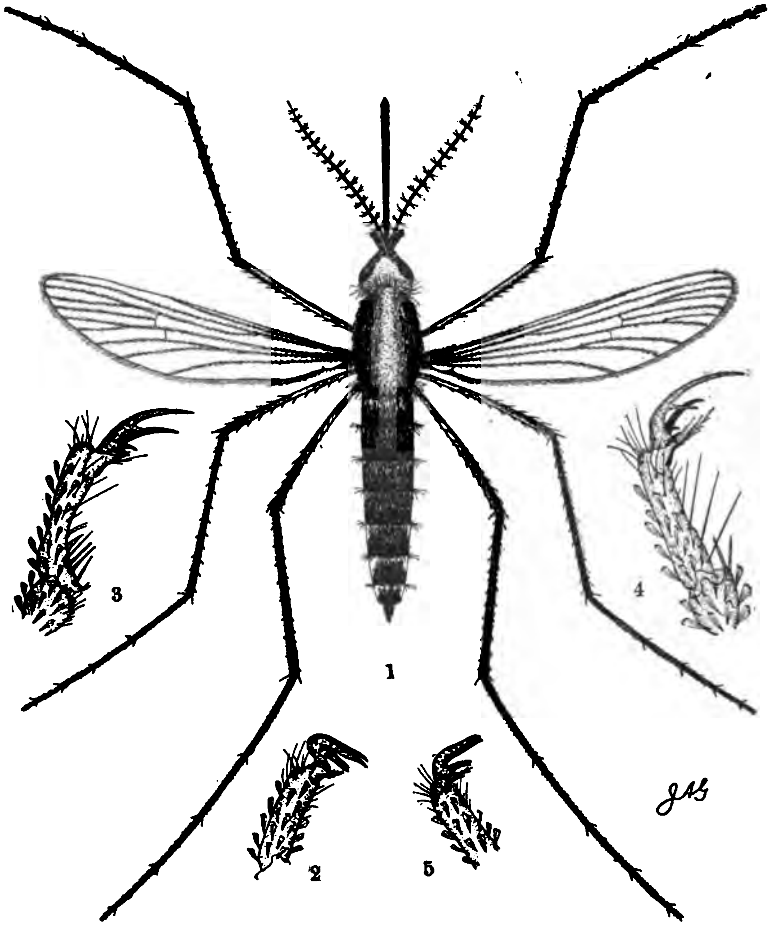

Figure 87.

Culex dupreei: 1, adult female; 2, her anterior claw; 3, anterior, 4, middle, 5, posterior claws of male: all much enlarged. (Original.)

diffused with whitish scales that cover the whole mesonotum. The pleura are brown. The femora are chiefly yellowish, with some brown scales on the dorsal surface, while the tibiæ and tarsi are blackish brown. In the male the claws of the anterior

and mid tarsal joints (figs. 87, 3 and 4) are unequal in size, the larger with a median and small basal tooth, the smaller with a small tooth near the base; the posterior claws (fig. 87, 5) are equal, the apical two-thirds at right angles to the base and each with a large basal tooth. In the female the claws are alike on all feet (fig. 87, 2), equal, hook-shaped and each with a large curved tooth near the base.

The abdomen is covered with brown scales, black at the apices of the segments; beneath white, the white extending up the sides and showing slightly on the dorsum at the basal angles of the apical two or three segments.

Habits of the Adult.

Very little is known of this small species, which has never been taken by any of the collectors in the adult stage. In 1904 it was taken only once, in any stage, despite careful search in the localities where it was found in 1903. It is scarcely probable that it bites, and it certainly cannot be classed as a pest in any sense. It was originally taken by Dr. Dupree, of Baton Rouge, La., and its occurrence in New Jersey was unexpected. Nothing is known of the method of hibernation, nor of the manner in which the eggs are laid.

Description of the Larva.

The larva (fig. 88, 1) is a small, inconspicuous wriggler, averaging 5.5 mm., = .22 of an inch in length, exclusive of the anal siphon, though specimens are rarely 6.5 mm. It is dirty white or yellowish in color, almost transparent and very difficult to see in the water; when placed in alcohol it becomes darker. The head is yellow with a faint cloud on the vertex, almost twice as broad as long and evenly rounded in front. Six hairs arise from the anterior part of the head, four in the central part and one from the base of each antenna. The antenna (fig. 88, 5) is short, half as long as the head, and pale yellow in color. It is almost uniform in thickness two-thirds from the base, then tapers slightly toward the tip, where there are four short spines and a small joint; the surface sparsely set with small, stout spines. The eyes are rather small and occupy the part where the head is widest. The rotary mouth brushes (fig. 88, 3) are very dense, the hairs pectinated at the tip, most obviously so in the center of the structures. The mandible (fig. 88, 4) is normal, with a

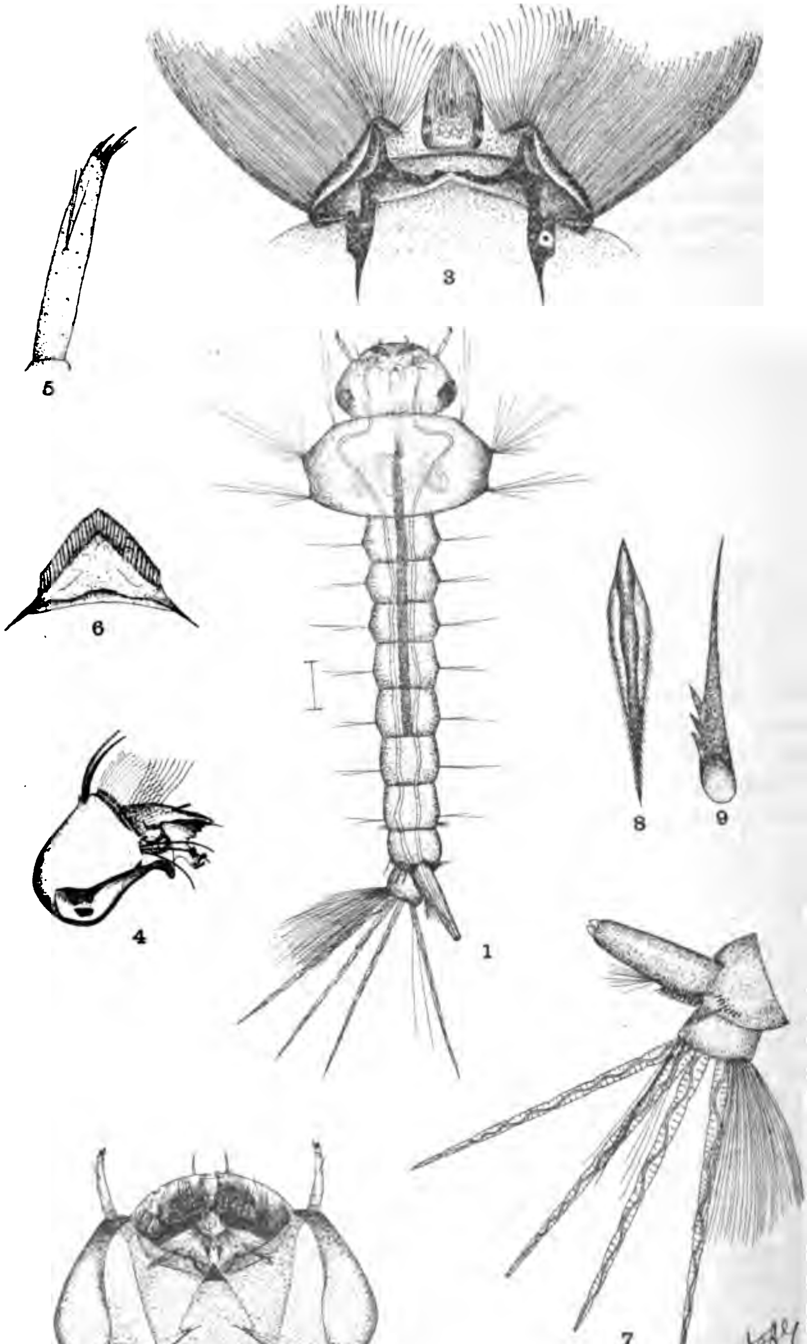

Figure 88.

Culex dupreei: 1, larva; 2, head from beneath; 3, mouth brushes; 4, mandible; 5, antenna; 6, mentum; 7, terminal segments, showing siphon and tracheal gills; 8, scale of the 8th segment; 9, a siphonal spine: enlarged. (Original.)

few small spines on the dorsal part of the base. The maxillary palpus is short and broad, with a rather large apical tuft and large, stout, basal joint. The mentum (fig. 88, 6) is triangular in form, with thirteen to sixteen small teeth of uniform size on each side of the apex.

The thorax is one and one-half times the width of the head, the sides angulated, each angle with moderate cream colored tufts, and two small, two-haired tufts on the anterior margin.

The abdominal segments 1 to 7 are subquadrate in form, with two hairs to each lateral tuft. The eighth segment has lateral combs of scales arranged in single regular curved rows, as shown in figure 88, 7. Each row consists of seven to twelve elongated scales, very acute at the apex and fringed at the sides with short, fine hairs (fig. 88, 8). The anal siphon in length is four and one-half times its width at the base and tapers rather evenly toward the tip. It is a very inconspicuous affair and readily overlooked in the living larva. The lateral rows of spines consist each of from nine to thirteen in number and extend one-third the length of the siphon from the base. The individual spines are slightly curved, their apices drawn to a long, slender point, the base rather broad with three or four teeth (fig. 88, 9). The ninth segment is almost square, completely ringed by the chitinized saddle; the ventral brush is rather large, composed of ten or twelve tufts of hair, which are confined to the barred area; the double dorsal tuft small, each tuft with one long hair. The anal gills are very long and slender, pointed at the apex, the lateral margins scalloped, the tracheal tubes plainly visible through them.

Habits of the Early Stages.

The species was first found in the larval stage by Clarence Van Duersen in a woodland pool near New Brunswick, July 29th, 1903. Several other species were associated with it, but this larva was at once recognized as distinct by its unusually long anal gills, the very small breathing tube and by its habit of remaining close to the bottom—a very unusual one for a mosquito larva. While in confinement the wrigglers never rose voluntarily to the surface, and when disturbed sailed rather than wriggled upward, descending immediately when quiet was restored. So inconspicuous and transparent are they, that a jar containing them would be set aside as empty unless critically examined, and this, together with their habit of hiding among leaves at the bottom of pools, renders them difficult to secure.

A number of pupæ were brought in with the larvæ and from these adults of both sexes were obtained. Several larvæ pupated and matured, giving an average duration of three days in that condition. The pupa is normal in appearance.

Other collections were made at the same place August 13th, when full-grown larvæ and pupæ were obtained, and September 3d, when half-grown larvæ only occurred.

Mr. Grossbeck found the larvæ in woodland pools in the Great Piece Meadow, September 9th and 10th, fully developed and in the pupal stage. Adults were obtained after an average stay of four days in the pupal stage. September 24th half-grown larvæ were found in the same place; but none of these were brought to maturity. September 29th, he found larvæ on the Garret Mountain near Paterson. It is probable, of course, that the species will be found in other parts of the State where there are low, swampy, dark woodland areas.

The record indicates continuous breeding from the middle of July to the end of September, and it may begin much earlier. This question could not be settled in 1904, because of the extremely dry conditions early in the season.

CULEX TRIVITTATUS, COQ.

The Three Striped Mosquito.

This species is recognizable by the three black, longitudinal stripes with a pale yellow background on the dorsum of the thorax. The legs and beak are unbanded, the wings unspotted and the abdomen has white lateral marks which often cross the dorsum at the base of the segments.

Description of the Adult.

This is a medium-sized mosquito, the body exclusive of the beak measuring 5–5.5 mm.,=.20–.22 of an inch in length; the beak 2.5 mm. long or almost half the length of the body. The head is covered with pale yellowish or grayish scales, darker at the sides; the proboscis black, without marks; the palpi in the female black, with the terminal joint small, bluntly pointed at the apex and flat at the base. In the male they are black, without rings, and shaped like those of *C. canadensis*. The antennæ are brown in both sexes with the basal joint of the male yellow. The thorax is pale yellow with three black, longitudinal stripes

on the dorsum, the central not reaching the posterior margin of the mesonotum; the pleura dark brown with patches of grayish white scales. The legs are black with the under sides of femora pale yellow. The claws of the male in the anterior and mid tarsal joints (figs. 89, 2 and 3) are unequal in size, the larger with a median and basal tooth, the smaller with a single tooth near the

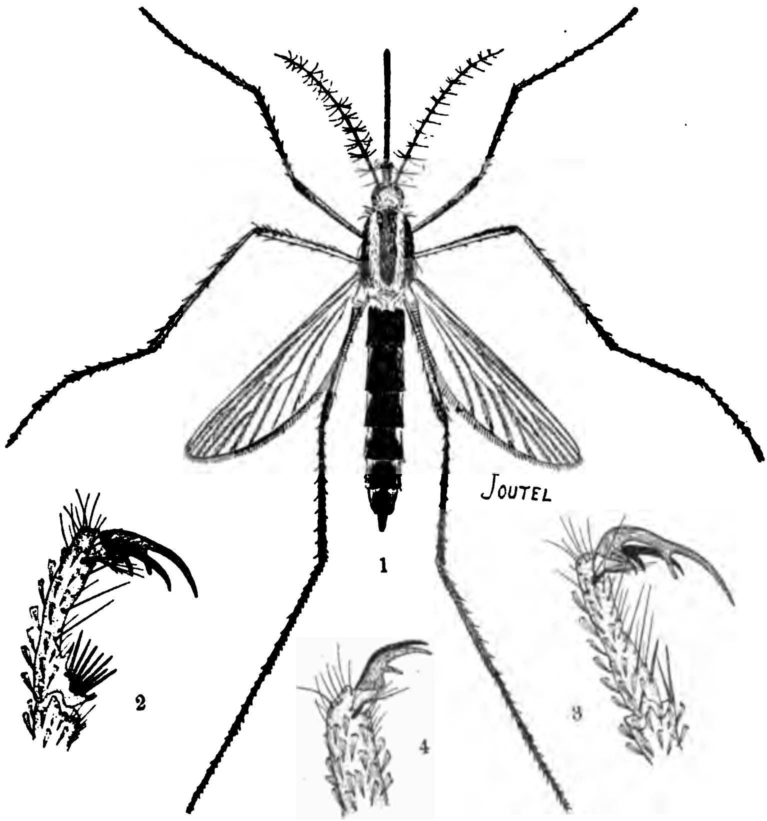

Figure 89.

Culex trivittatus: 1, adult female; 2, anterior, 3, middle, and 4, posterior claws of male: all enlarged. (Original.)

base. The claws of the posterior tarsal joint (fig. 89, 4) are equal, each with single median tooth slightly nearer the base. In the female the claws are alike on all feet, equal and with one tooth in the centre of each, like the posterior ones of the male.

The dorsum of the abdomen is black, the venter whitish, the white extending up the sides at the base of the segments and upon

the dorsum, at the front angles of the posterior segments. These lateral marks often continue narrowly across the abdomen, especially in the males.

Habits of the Adult.

This is another woodland mosquito, and one which has not, up to the present time, been found in towns or even on porches of buildings surrounded by trees. It has never been found indoors, anywhere. The species breeds in some numbers on the ridge back of South Orange, but none of the specimens taken in that place were referable to this species. Outdoor captures were made July 2d, at Trenton, by Mr. Grossbeck; July 4th and 5th, at Chester, by Mr. Dickerson; July 13th, at Summit; July 17th and 18th, at Deckertown; July 21st and 22d, at Lake Hopatcong, all by Mr. Grossbeck; August 25th, at Jamesburg, by Mr. Marsh, and September 3d, in the Great Piece Meadow, by Mr. Brehme. All these localities are from the more northern section of the State and none are south of the red shale except the Jamesburg locality. All the collectors report that this mosquito is fierce in its attack, but not one was really bitten. The insects seemed to tackle low—that is, they rarely came above the knees, Mr. Grossbeck being especially emphatic on this point. The result was that these parts, being protected by the clothing, did not suffer, while the insect yet gave an exhibition of its good intentions in the matter.

Description of the Larva.

The larva (plate 90, fig 1) is a stout, robust wriggler, measuring 7–7.5 mm.,=.28–.30 of an inch, to the tip of the ninth abdominal segment. The body is dark gray, with the exception of the head, siphon and anal segment. The head is rather small, one-third wider than long and evenly rounded in front; in color yellowish with large dark brown blotches which give the predominating shade. From the anterior part of the vertex arise four single hairs, each from a separate pit; the pits so arranged as to form a square, narrower in front; a small tuft of four or five hairs at the base of each antenna. The antenna (fig. 90, 2) is short, evenly tapered apically, yellow in color, becoming very dark brown toward the apex; the surface set with rather large spines with very small ones intermingled. The tuft, consisting of eight or ten hairs, is situated on the shaft slightly below the middle and the apex has one long spine,

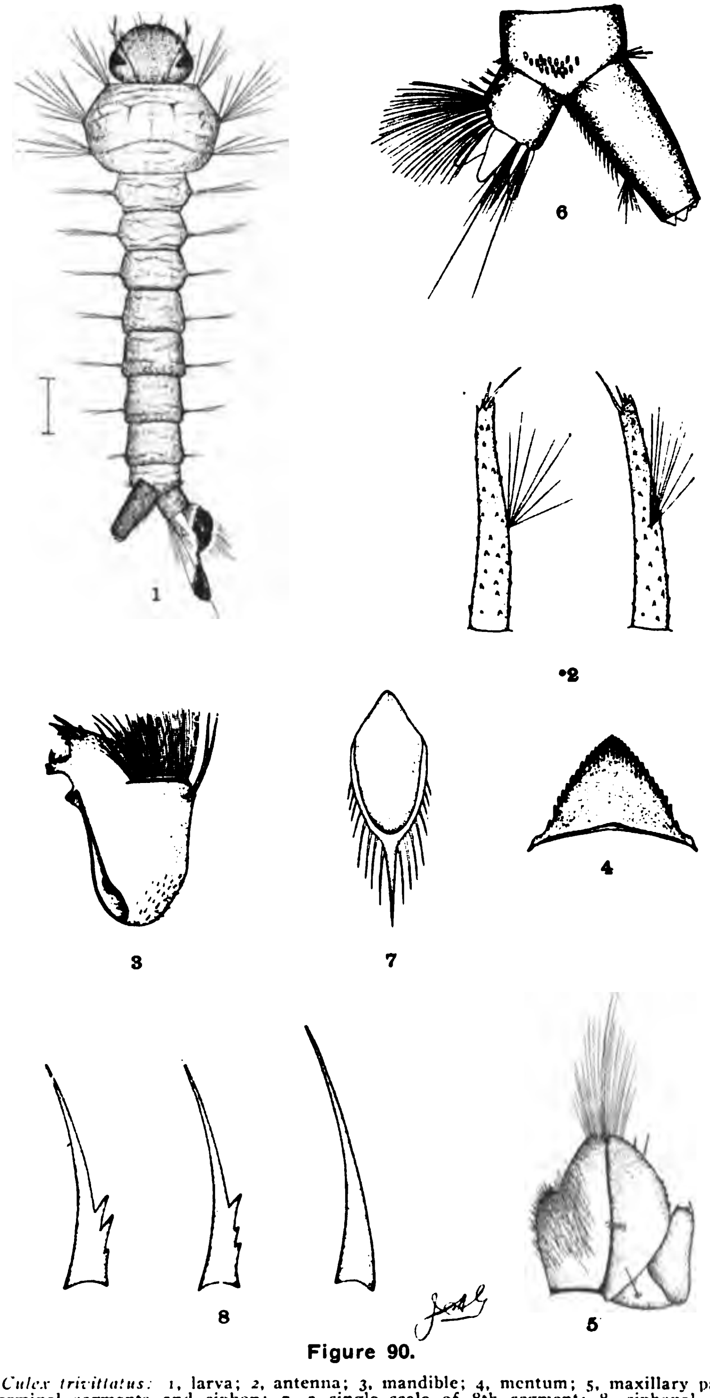

Figure 90.

Culex trivittatus: 1, larva; 2, antenna; 3, mandible; 4, mentum; 5, maxillary palpus; 6, terminal segments and siphon; 7, a single scale of 8th segment; 8, siphonal spines showing variation: all enlarged. (Original.)

two shorter ones and a small joint, all articulated. The eyes are normal, usually with a broad, pale yellow ring. The rotary mouth brushes are pectinated on the apical third of the more central hairs. The mentum (fig. 90, 4) is triangular in form with slightly curved sides of fifteen small teeth each. The mandible (fig. 90, 3) has small spines on the dorsal surface of the base and the maxillary palpus (fig. 90, 5) has a moderate apical tuft, a rather large basal joint and patches of hair over the surface.

The thorax is large and stout, with two transverse depressions and smaller transverse wrinkles on the dorsum. The sides are angulated, each angle giving rise to long hair tufts, and there are two very small hair tufts on the anterior margin.

The abdominal segments are chunky, the anterior two broad, with four or five hairs in each lateral tuft; segments four to seven subquadrate, with two hairs to the lateral tuft, save the seventh, which has small tufts only. The lateral combs of the eighth segment have each fourteen to twenty-two scales, with arrangement as shown in figure 6. The single scale (fig. 90, 7) is broad, with a rather long acute barb and several smaller ones on the sides, becoming shorter toward the base. The anal siphon (fig. 90, 6) is short, about two and one-half times as long as its width at the base, dark brown, almost black in color and with the valves slightly dilated, so as to flare at the tip. The spines composing the double row are curved, with two or three teeth at the base, the terminal one sometimes without teeth. There are from thirteen to eighteen spines in each row. The ninth segment is almost square, completely ringed by a chitinized saddle the same color as the siphon. The ventral brush is moderate, with two or three small tufts below the barred area. The double dorsal tufts are normal, each with a very long hair as usual. The anal gills are short, about the same length as the ninth segment.

Habits of the Early Stages.

Very little is actually known concerning the early stages, full grown larvæ and pupæ only being at hand. It is probable that the species winters in the egg stage, and that it is not an early species. The larvæ were first taken during the last days of June by Messrs. H. H. and E. Brehme from pools in the woodlands back of South Orange, in company with *sylvestris* and *musicus*, and additional material obtained July 2d showed the same combination of species. Collections made August 11th and 12th in the Hatfield swamp by Mr. H. H. Brehme turned out a few more

examples mingled with *sylvestris*, and that completes the record. As compared with the other larvæ that of *trivittatus* was always rare and only a very few examples were obtained for preservation. It seems to be one of those species in which the larvæ develop very evenly, for only the full grown wrigglers and pupæ were collected. As to the character of the breeding pools these are the usual depressions occurring in woodland; kept moist by shade and small springs, so as to fill readily during a heavy rain and kept up by the same factors long enough to bring even the slow-growing larvæ to maturity. Nothing is definitely known as to the length of any period.

CULEX PRETANS, GROSSBECK.

The Brown-striped Mosquito.

A dark brown species with legs and beak unbanded, the thorax yellowish with a broad median brown stripe and a smaller mark of the same color on each side of the posterior third. The abdomen is brownish black with narrow white basal bands, which become wide at the sides.

Description of the Adult.

This is a medium sized mosquito measuring about 5 mm., = .20 of an inch in length exclusive of the beak, which is over 2 mm., or nearly half the length of the body. The occiput of the head is dark brown, almost wholly covered with pale yellow scales, some of which collect into a distinct border to the eyes, and on each side is a small patch of dark brown scales. The palpi of the female are dark brown in color, of the normal *Culex* form; but the terminal joint is almost obsolete; in the male they are of the same shape as in *C. canadensis*, dark brown, almost black. The antennæ are dark brown in both sexes, with the two basal joints in the female pale testaceous.

The thorax is covered with yellowish scales and has an usually well defined broad median stripe of brown scales, which begins almost at the anterior margin and is slightly constricted centrally; there are also two other patches of brown scales about one-third the length of the thorax, at the base of this stripe, on each side and separated by a narrow line of yellow scales. The pleura are very dark brown, with patches of pure white scales. The legs are dark brown, almost black, with the under sides of the tibiæ pale yellow and of the femora creamy white, with a

dot of the same color at the apex. The claws of the male anterior and mid tarsal joints (fig. 91, 2 and 3) are unequal in size, the larger with a blunt median tooth and a very acute basal one, the smaller with a single tooth near the base. The posterior claws (fig. 91, 4) and all those of the female are equal in size, each with a median tooth nearer the base.

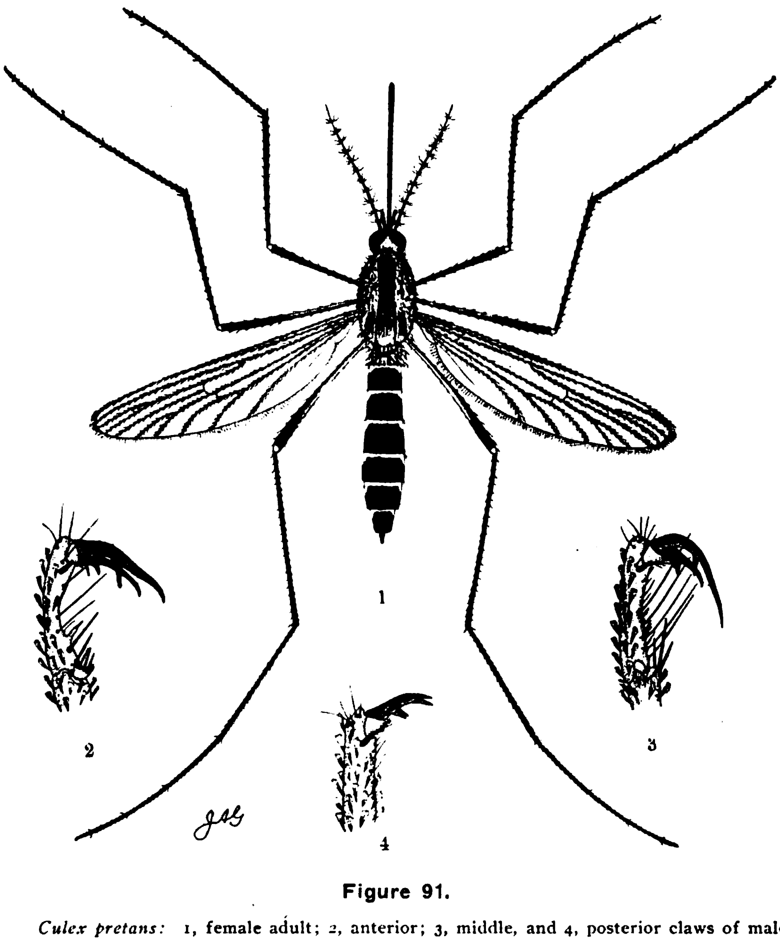

Figure 91.

Culex pretans: 1, female adult; 2, anterior; 3, middle, and 4, posterior claws of male: all enlarged. (Original.)

The abdomen is brownish black, with narrow white basal bands which widen at the sides, until beneath it is wholly whitish. The bands are usually clearly defined, and though narrow are rarely obsolete.

Habits of the Adult.

This species is rather rare and has not been taken south of Trenton. It occurs among the early species that develop in woodland pools, two examples being bred, May 12th, from pupæ taken in the Great Piece Meadow. Additional specimens were taken July 18th at Trenton, July 21st at Lake Hopatcong, July 30th at Chester, September 10th and 16th at Chester.

Both Mr. Grossbeck and Mr. Dickerson say that in its general habits it does not differ from the other woodland mosquitoes, and while it bites, it is not vicious and causes no unusual pain or swelling. Of its method of passing the winter we know nothing definite; but it is likely that it is in the egg stage.

This is the species that was referred to as *reptans* in Bulletin No. 171 of the Experiment Station. It seems, however, that there is doubt whether *reptans* refers to a species distinct from the common *nemorosus* of Europe, and if it does, to which of the American forms the name should be applied. Under the circumstances it was deemed best to give this New Jersey form a distinct name, so that there might be no doubt as to just what species is intended.

Description of the Larva.

The larva and details are illustrated on figure 92. The full grown wriggler (the few larvæ in hand were undoubtedly full grown) measures 5.5–6 mm.,=.22–.24 of an inch in length excluding the anal siphon, and is pale gray to dark gray in color. The head is one and one-half times as broad as long, yellowish, with a large brown blotch on the anterior part of the vertex, similar to *C. sylvestris*. There are four hair tufts in the center of the vertex, of four or five hairs each, and a larger one at the base of each antenna. The antenna (fig. 92, 5) is rather short, slightly curved, pale yellow in color, faintly infuscated apically; thickest a short distance from the base and with the surface sparsely set with stout spines and numerous small ones arranged in longitudinal rows. The tuft is situated well below the middle and consists of eight or ten hairs which do not reach the apex; the apex with one long spine, several smaller ones and a small joint. The rotary mouth brushes are dense, with the hairs of the central part pectinated. The mentum (fig. 92, 2) is triangular in form with fifteen to seventeen small teeth on each side of the apex. The mandible and maxillary palpus (fig.

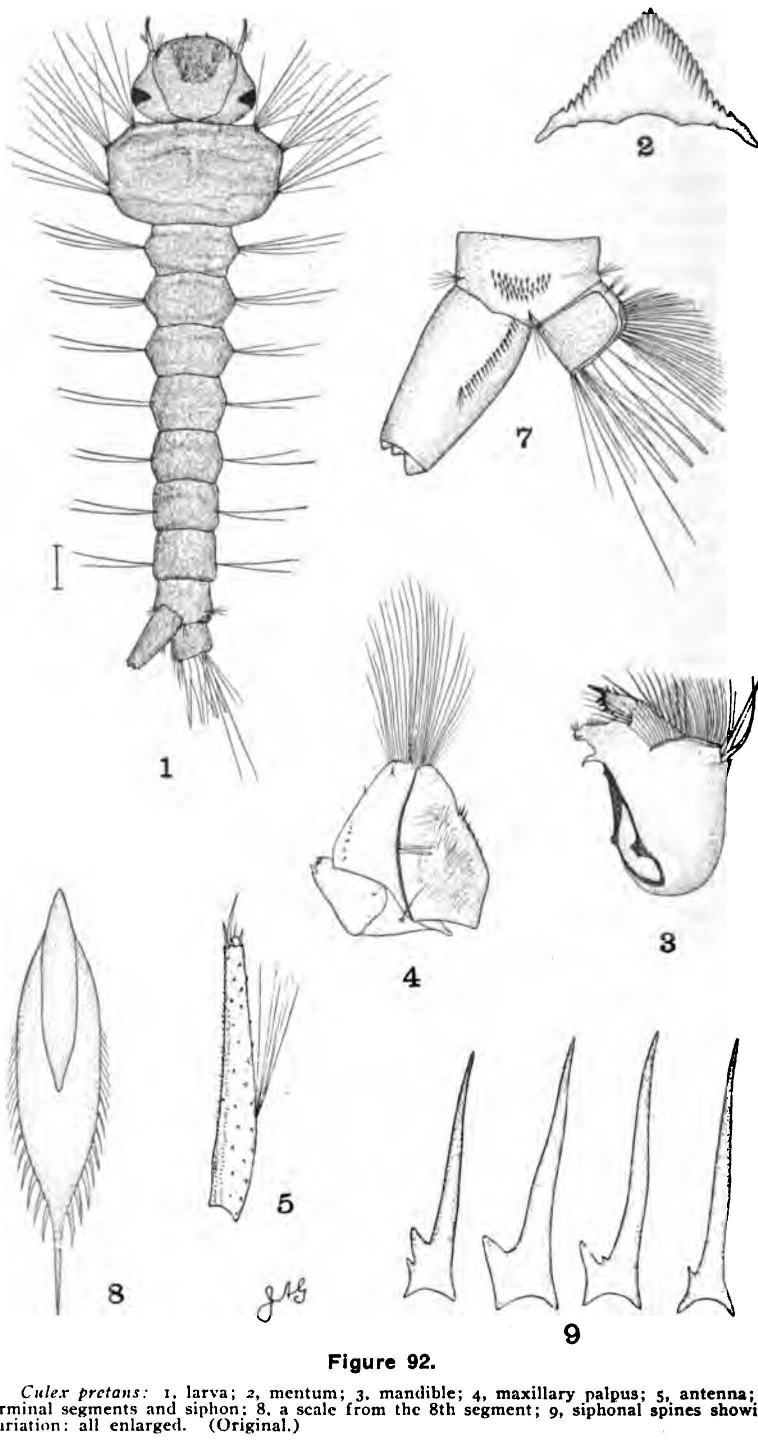

Figure 92.

Culex pretans: 1, larva; 2, mentum; 3, mandible; 4, maxillary palpus; 5, antenna; 7, terminal segments and siphon; 8, a scale from the 8th segment; 9, siphonal spines showing variation: all enlarged. (Original.)

92, 3 and 4) are normal, the latter with a moderate apical tuft and stout basal joint.

The thorax is very much broader than long, with angulated sides, each angle set with acute infuscated tubercles from which issue moderate sized hair tufts, and there are two very small tufts near the anterior margin. The abdominal segments are subequal, each bearing lateral hair tufts of from two to five hairs in each, the larger number on the anterior segments. The lateral patches of scales on the eighth segment are large, having from twenty-five to thirty in each patch. The individual scale (fig. 92, 8) is elongated, with a rather small apical spine and smaller ones fringing the sides. The anal siphon is two and one-half times, or slightly over, as long as broad, yellowish brown in color, thickest near the base and tapering a little apically. There are from sixteen to twenty spines in each of the rows, the single spine (fig. 92, 9) with one or two teeth near the base. The ninth segment is almost square, nearly ringed by the chitinized saddle and with the double dorsal tuft and ventral brush normal and moderate in size, the latter with several small tufts below the barred area. The tracheal gills are slender, about two and one-half times the length of the ninth segment and taper to a point.

Habits of the Early Stages.

A mixture of full grown larvæ and pupæ was taken from a woodland pool in the Great Piece Meadows May 10th, 1904, by Mr. Grossbeck. All the larvæ were put in alcohol and the pupæ in breeding jars to develop. During the next three days specimens of *C. canadensis, C. sylvestris* and *C. pretans* appeared in the jar, and no others. Examination of the larvæ showed those of *C. canadensis, C. sylvestris and Aedes fuscus* which were known to us, and one other which we had not previously recognized and which was assumed to be the early stage of *pretans,* as that was the only one we had not bred. The connection between the larva above described and the adult has not been positively made, therefore; but I have no doubt of the correctness of the association.

We failed absolutely to obtain this larva again, later in the season; but the territory where they had been found in May was unusually dry until after midsummer and none of the pools refilled so as to mature a brood.

CULEX INCONSPICUUS, GROSSBECK.

The Inconspicuous Mosquito.

A small mosquito, brown in color with the dorsal surface of the thorax very dark brown, covered with pale yellowish scales at

the sides defining a brown central stripe. The beak and legs are unbanded and the abdomen has bands of a dirty white color at the base of the segments.

Description of the Adult.

This is a very small mosquito, measuring 4-4.5 mm.,=.16-.18 of an inch in length excluding the beak. The head is dark brown and has many pale yellow scales scattered over the occi-

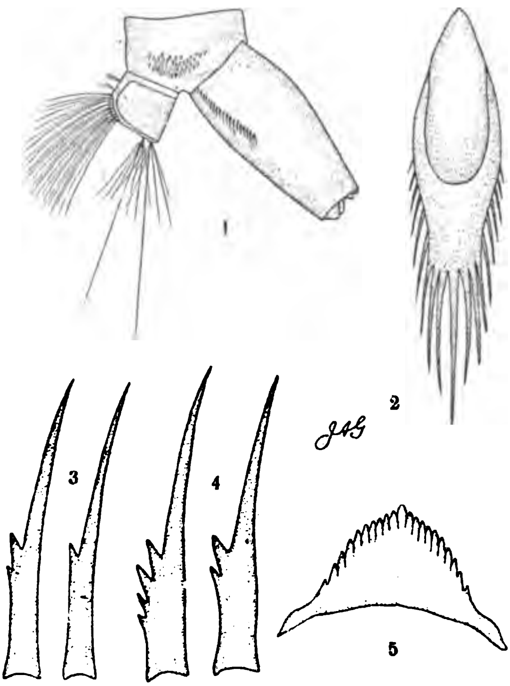

Figure 93.

Culex inconspicuus: 1, terminal segments with anal siphon; 2, a single scale of the 8th abdominal segment; 3, normal siphonal spines; 4, varietal forms of siphonal spines; 5. mentum: all much enlarged. (Original).

put; the proboscis and female palpi are dark brown, almost black, the former about half the length of the body. In the male the palpi are evenly dark brown, slender, dilated apically and longer than the proboscis by the terminal and half of the penultimate joints. The antennæ are brown in both sexes with the basal two joints in the female pale testaceous.

The dorsum of the thorax is dark brown, covered with pale yellowish scales at the sides, limiting a rather broad central stripe,

which is more or less well defined; the shoulders are covered with brown scales becoming diffused posteriorly in the yellowish scales. The pleura are brown with small spots of grayish white scales. The legs are wholly brown with the under side of the femora yellowish white; the small dot at the knee is almost imperceptible. The claws are precisely as in *C. pretans,* those of the anterior and mid feet unequal, the larger with a median and basal tooth, the smaller with a single tooth near the base. The male posterior claws and all those of the female are equal, each with a single median tooth nearer the base.

The abdomen is dark brown with basal bands of dirty white; in the female these bands are narrow and widen out laterally; beneath, pale brownish with scattered white scales, especially noticeable in the apical segments; in the male the bands appear darker, being mixed with some brown scales. They are narrow on the anterior segments, broader on the posterior and widen out laterally as in the female; beneath it is whitish with mixed brown scales.

Habits of the Adult.

This species was bred once only and four examples representing both sexes were obtained. They were determined as *reptans* by Mr. Coquillett, but are undoubtedly different from the other specimens caught and bred and labelled with the same name. The species was described by Mr. Grossbeck at my suggestion.

Description of the Larva.

Note.—The larvæ from which this species was bred began to die off in the breeding jar before it was known that we had a new species to deal with. Then, only *C. sylvestris* larvæ were left alive; but remnants at the bottom of the jar were placed in alcohol. In these remnants only the more strongly chitinized parts of the larvæ remained, the anal siphon and the head case; the antennal attachments seem to offer but little resistance to decomposition; only one head retained them and these were in such condition as not to allow a drawing to be made.

The larvæ present a general resemblance to *C. sylvestris*, but are much smaller. The mandibles and maxillary palpi are also similar to that species, but the sides of the mentum are more rounded and have fewer teeth—ten or twelve on each side of the apex (fig. 93, 5). The hairs of the rotary mouth brushes are

pectinated. The antennæ, as well as could be seen, were very much like those of *C. sylvestris*. The anal siphon (fig. 93, 1) is about three times as long as broad,* with sixteen to twenty-two spines in each of the lateral rows; the individual spines are rather slender and with one or two teeth near the middle, as in figure 93, 3, but in one larva the spines were stouter and one had as many as four teeth. The lateral patches are large, each with about forty to forty-five scales, the single scale (fig. 93, 2) with long, slender apical spines and shorter lateral ones. The ninth segment is as broad as long, not quite ringed by the saddle and with the double dorsal tuft and ventral brush moderate in size, the latter with small tufts below the barred area. None of the specimens retained the tracheal gills.

Habits of the Early Stages.

The larva was found once only, by Mr. Grossbeck in a woodland pool, on the Garrett Mountain, near Paterson, September 29, 1903. In 1904 the season was so dry that there were no pools when collections were attempted, and circumstances prevented collections late in the season. Nothing is therefore known of the early stages other than has been already stated.

CULEX AURIFER, COQ.

The Golden Scaled Mosquito.

This mosquito is characterized by its long, black, unbanded legs, the femora yellow inwardly, unbanded beak and uniformly colored abdomen. On the sides of the thorax are golden yellow scales, leaving a black central band on the disc; the posterior part of the disc also has yellow scales arranged in longitudinal lines.

Description of the Adult.

This species is of medium size and not very robust. The body is 5½ mm., or not quite one-quarter of an inch, in length; the beak is about one-half the length of the body and the wings when expanded measure 10 mm., or .40 of an inch across. The sides of the head are taken up by the large black eyes which almost

* The specimen drawn was under pressure and is, consequently, wider.

meet on top of the anterior part. The vertex back of the eyes is clothed with golden yellow scales. The beak is black, the palpi in the female (fig. 94, 2) short, four-jointed, the two central

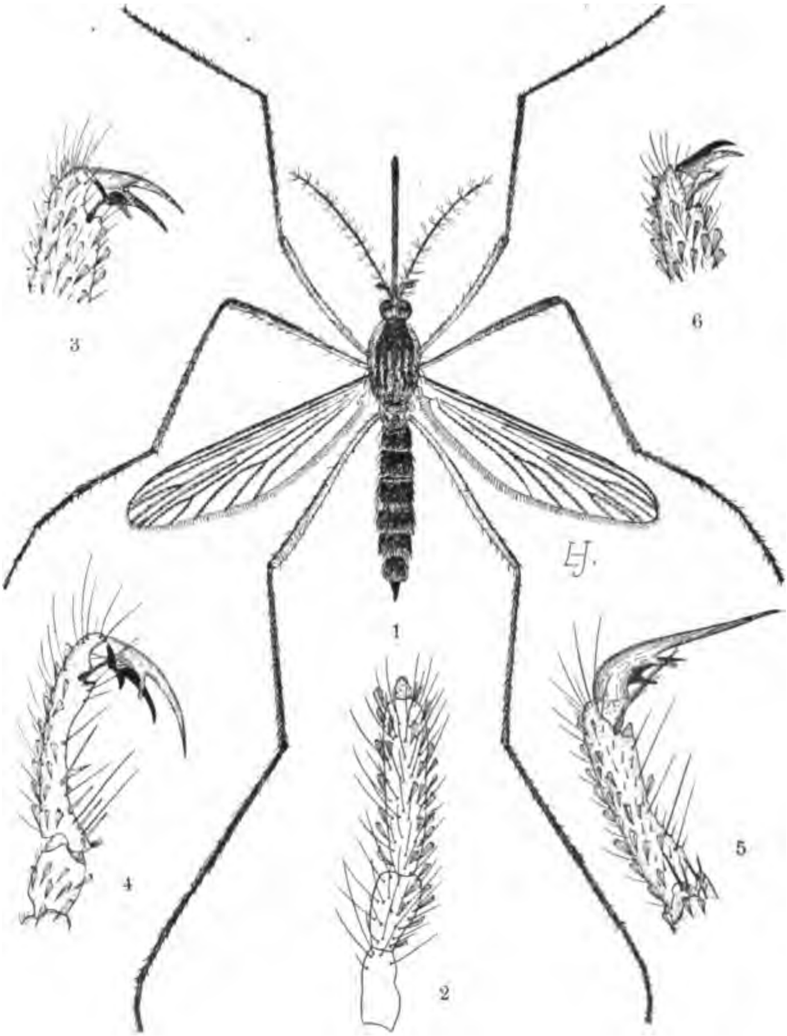

Figure 94.

Culex aurifer: 1, female adult; 2, her palpus; 3, the anterior claws; 4, anterior, 5, middle, and 6, posterior claws of male: enlarged. (Original.)

joints set with scales and moderately long, bristle-like hair; the apical joint small, slightly longer than wide, covered with fine short hair, and the basal segment destitute of scales, but with a

few hairs on the apical part. The male palpi (fig. 41, 1) are longer than the beak, black, with some of the hairs of the fan-like tufts, whitish, and the stalk of the basal segment with a slight angulation near the middle. The antenna of the male is plumose, blackish, with twelve cup-like joints surrounded with a circle of fine long hair, and two long, slender, terminal segments set with fine short hair; the base of the apical one with a circle of six long bristles.

The female antenna has usually twelve long, narrow joints covered with short hair, and each set with six long bristles at the base.

The thorax has an undefined black central band, broken in the posterior part by irregular lines of golden yellow scales and edged with scales of the same color which extend for a short distance down the sides and intermingle with a patch of white scales. The legs are all black, with the femur and inner side of the tibia yellowish. In the male the anterior claw joint (fig. 94, 4) is excavated inwardly, and set with moderatelv long, bristle-like hairs; the inner claw is much longer than the outer, and both have a single median tooth slightly nearer the base. The claw joint of the mid tarsi is curved a little inwardly; with one very long claw, sharply curved at the base and a long, straight, tapering point, and one rather short claw; both with a long slender tooth near the base. The hind claw joint is long, with two very small, single-toothed claws of equal size.

The claws of the female are alike on all feet, of equal size and with one tooth a short distance from the base.

The abdomen is black on the dorsum, with faint white lines separating the segments, and pale yellow on the venter.

Habits of the Adult.

Though *aurifer* is by no means common anywhere, it is one of the most blood-thirsty species we have. It has never been found far away from its breeding places and does not enter houses, but does fly for some distance at night, and is not so closely confined to the woods as *canadensis*. If its haunts are entered during the day it attacks fiercely and fearlessly. Mr. Brakeley, who is the only person known to me who has any considerable personal acquaintance with this species, several times refers to this point in his notes and mentions the fact that when once the insect has tasted blood it is almost impossible to drive it off and it may be taken without difficulty. After several field experiences an op-

portunity for closer observation came June 21st about 7 A. M., when an *aurifer* alighted on Mr. Brakeley's left hand. I give the substance of his notes made at the time: She punctured the skin, got down to blood and was happy. Took the little tweezers and began to tease her. She kicked, shook her head, was annoyed, and after five to ten seconds she let go, having only a small quantity of blood. Got on another place and made a second puncture undisturbed, but as soon as she began to feed the teasing recommenced. She "kicked like a mule," and was dislodged with difficulty, returning to the attack in a third place. She was again allowed to pierce the skin though this seemed more difficult and was again irritated until she let go. Nevertheless she returned to the attack and in a different place made a fourth puncture. This time the mouth structures were "wobbly," and there was difficulty in making the puncture, but she succeeded and was allowed to become about three-fourths full. Then the teasing began again and, although she hung on tenaciously she was again dislodged. Apparently her appetite was unsatisfied, for she made yet another attempt to bite. But, though she was undisturbed and was allowed to try as she would, she failed in making the fifth puncture and flew reluctantly away.

The earliest date for adult *aurifer* is April 23d, the latest for larvæ is May 10th, from which the adult was bred May 13th. Adults were taken as late as July 24th, yet blood-thirsty, and occurred in considerable swarms during the last days of June. This would indicate an adult life period of nearly three months—much longer than we have been inclined to credit them with. It seems scarcely possible that a summer brood of larvæ could have been overlooked, since Mr. Brakeley collected continuously through June, and the Orange Mountains and Great Piece meadows were looked over again and again during the entire season.

The dates above given are all from Lahaway, so that no objection can be made that the extremes are from different climatic conditions. That the matter was held in mind, Mr. Brakeley's notes of June 25, 1903, show clearly. He made a trip into *aurifer* territory, ran into a swarm and "the whole shooting match made a dive for me, prompted by a thirst from end to end; bill first and legs last." So thirsty were they and so much in a hurry that they did not even stop to sing, and so eager in sucking that there was no trouble in bottling the specimens that had gotten a hold. All the pools nearby were examined closely, but no larvæ, pupæ or signs of recent development were observed. The places where the larvæ had been found early in the season were then dry.

Previous to that, on May 29th, while one of the reservoirs was

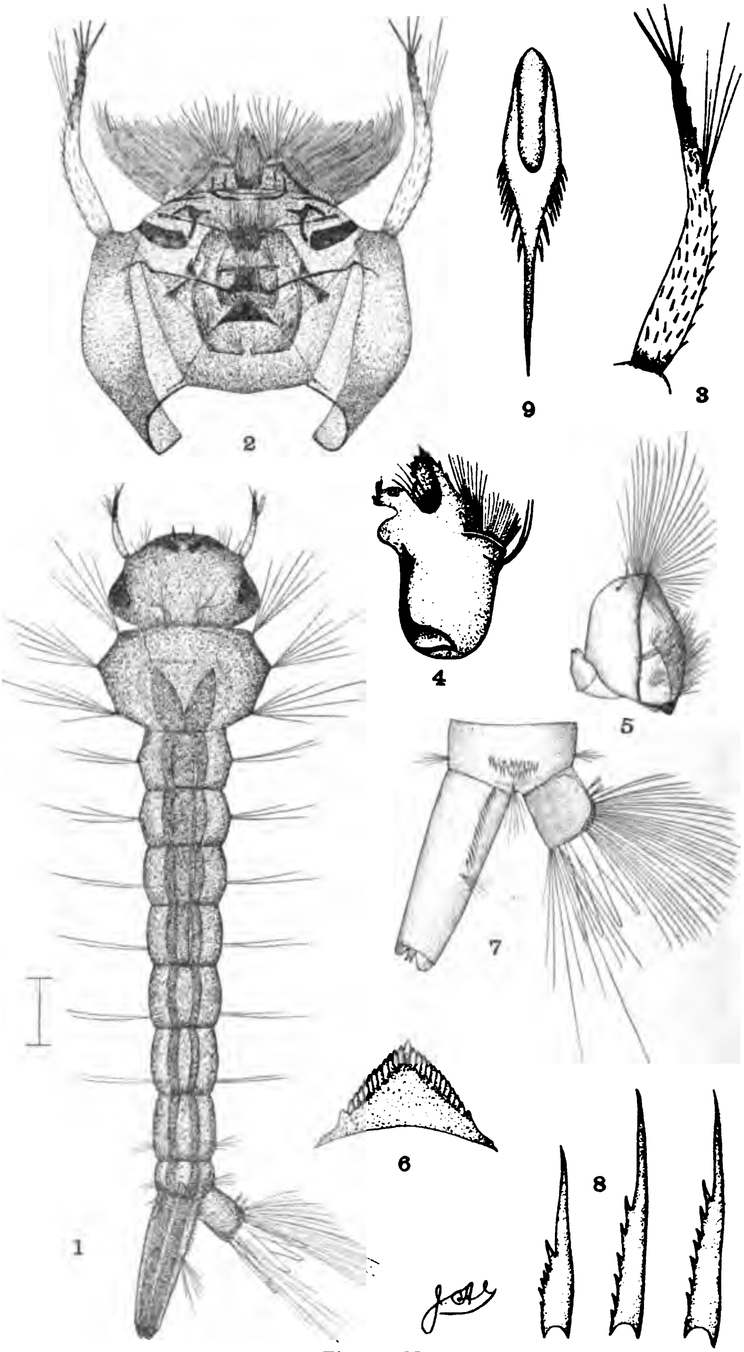

Figure 95.

Culex aurifer: 1, larva; 2, head from below; 3, antenna; 4, mandible; 5, maxillary palpus; 6, mentum; 7, terminal segments with anal siphon; 8, siphonal spines showing variation; 9, a single scale of the 8th segment: all enlarged. (Original.)

yet water covered, a very careful examination was made and all the places where larvæ were earlier taken were tested—without result so far as obtaining larvæ was concerned.

Description of the Larva.

The larva and some details of structure are illustrated on plate 95. When full grown, the larva (fig. 95, 1) measures 7–9 mm., = .28–.36 of an inch to the end of the ninth segment. Specimens are usually grayish or brownish black, though, rarely, they are rusty and almost brick colored. The head is transversely elliptical, nearly as large as the thorax, broadest immediately behind the eyes. Two tufts, situated close together and each composed of two hairs, arise from each side of the head slightly lower than the antennæ, and one large tuft is directly at the base of each antenna. Eyes moderate in size, antenna (fig. 95, 3) white, tipped with black, almost half as long as the head is broad, thickest near the base, tapering slightly to about the middle, then curved inwardly, becoming very narrow distally, the apex with three long spines, one short one, and a little joint. The tuft consists of from six to ten long hairs and is situated above the middle, at the obtuse angle formed by the curve. The surface is set with small stout spines, concolorous with the antenna. The rotary mouth brushes are large and composed of simple hairs. The mentum (fig. 95, 6) is broadly triangular, with eleven or twelve teeth on each side of the apex. The mandible (fig. 95, 4) is normal and is best described by a reference to the figure. The maxillary palpus is clothed with soft, fine hair, arranged in patches, has a large, long tuft at the apex and a little joint at its base, with small articulated spines at its blunt tip.

The thorax is transverse, edges of the segments so marked as to form three angles with tubercles from which arise tufts of long hair. Two smaller tufts are on the cephalic margin.

Abdominal segments 1 to 6, inclusive, have lateral tufts of long hairs, while segments 7 and 8 have the tufts much reduced in length. The combs of the eighth segment have from eighteen to twenty-eight fringed scales (fig. 95, 9) in each patch, arranged as shown in figure 95, 7. The anal siphon is three and one-half times as long as broad, with straight sides and does not taper much toward the apex. The lateral rows of spines consist each of fourteen to twenty toothed spines. The individual spine (fig. 95, 8) is much broadened at its basal half and with five to seven teeth. The ninth segment is a little longer than wide, with

the usual double tuft, each having one very long hair on the dorsal part of the apical margin. The barred area on the ventral part, with ten to twelve tufts of five or six hairs each. The anal gills are moderately long, without obvious tracheæ.

Habits of the Early Stages.

Practically all our knowledge of this species comes from Mr. Brakeley's observations, though in 1904 Mr. Grossbeck took larvæ in the Great Piece Meadow, May 10th, from which a male adult was obtained May 13th, as against a dozen *canadensis* which emerged on the same date. Mr. Brehme, in collections of larvæ and pupæ made at Arlington, May 9th, also had one male of this species, which emerged May 13th. This indicates a somewhat general distribution in the State, but a rare occurrence at any point. No one save Mr. Brakeley has taken the adults in New Jersey, and all who have taken the larva have found it associated with that of *canadensis*.

The captures of Messrs. Grosbeck and Brehme were purely accidental, while, after I once recognized the larva as distinct, Mr. Brakeley's takings were intelligent, the species being recognized as soon as attention was called to it. As a matter of fact, indeed, Mr. Brakeley himself recognized the larva as unlike the general run of those that he was taking.

The larva first came under my observation in the early spring of 1902, a single specimen being in material sent in from Lahaway by Mr. Miller Emley, under instructions from Mr. Brakeley. It was not bred and escaped attention until it was too late to search for other specimens. At that time I believed that I had the larva of *perturbans*, then the only species known to me from Lahaway of which I did not have the early stages.

In 1903 Mr. Brakeley sent in the first larvæ, March 23d, as extra large *canadensis*. Being advised of the difference, he found them afterwards in the larger bodies of water covering the bogs and reservoirs and in pools of considerable size nearby, always associated with *canadensis* and always comparatively rare. They do not hug the edge of the pool so generally as do some of the other species, but favor tufts of grass, rushes or vines several feet from shore. Larvæ only were collected until April 14th, at which time the first pupa was taken. Thereafter larvæ and pupæ were taken until well along in May, the latest actual date at which either larvæ or pupæ occurred being May 13th. No *aurifer* larvæ have been collected with the earliest *canadensis*, and from

such data as I have at hand it seems that the eggs begin to hatch during the early days of March and that the larvæ grow quite rapidly at first, as though they might produce the earliest adults. But they linger in the last stage, and the first pupæ require from five to nine days to mature.

Eggs of *aurifer* have not been obtained by me; but there seems little doubt that they are laid like those of *canadensis*, though probably different in form. The water is drawn from the bogs before the *aurifer* adults disappear, hence the eggs must be laid in the bog mud, where they rest until they become water covered again in late fall and hatch in the spring following. I have no evidence that there is more than one brood of this species. The pupa is recognizable from that of *canadensis* by its decidedly larger size and white air tubes.

CULEX PIPIENS, LINN.

The House or Rain-barrel Mosquito.

Small or medium in size, brown or yellowish in color, with rather narrow, but well-defined white bands at the base of the abdominal segments; legs and beak unbanded and the wings unspotted.

Description of the Adult.

This is a mosquito of medium size, though small individuals are common. It ranges from 4 to 5½ mm.,=.16–22 of an inch in length exclusive of the beak, which is about half the length of the body. The wings expand 7 to 10 mm., according to the size of the insect. The head behind the large black eyes is brown, with a few yellowish scales and a distinct yellow border to the eyes; the beak is brown, darker toward the apex, and is somewhat thicker and shorter in the male than the female. The palpi (fig. 96, 2) in the female are fuscous grayish at the extreme apex and apparently three jointed, the terminal one pointed and wholly retracted within the third joint; the antennæ are dark brown. In the male the antennæ are ochraceous brown, the palpi of the same color, whitish beneath at the bases of the two apical joints; as in *C. melanurus* they are not dilated, but the two terminal joints are comparatively much longer and the basal joint shorter.

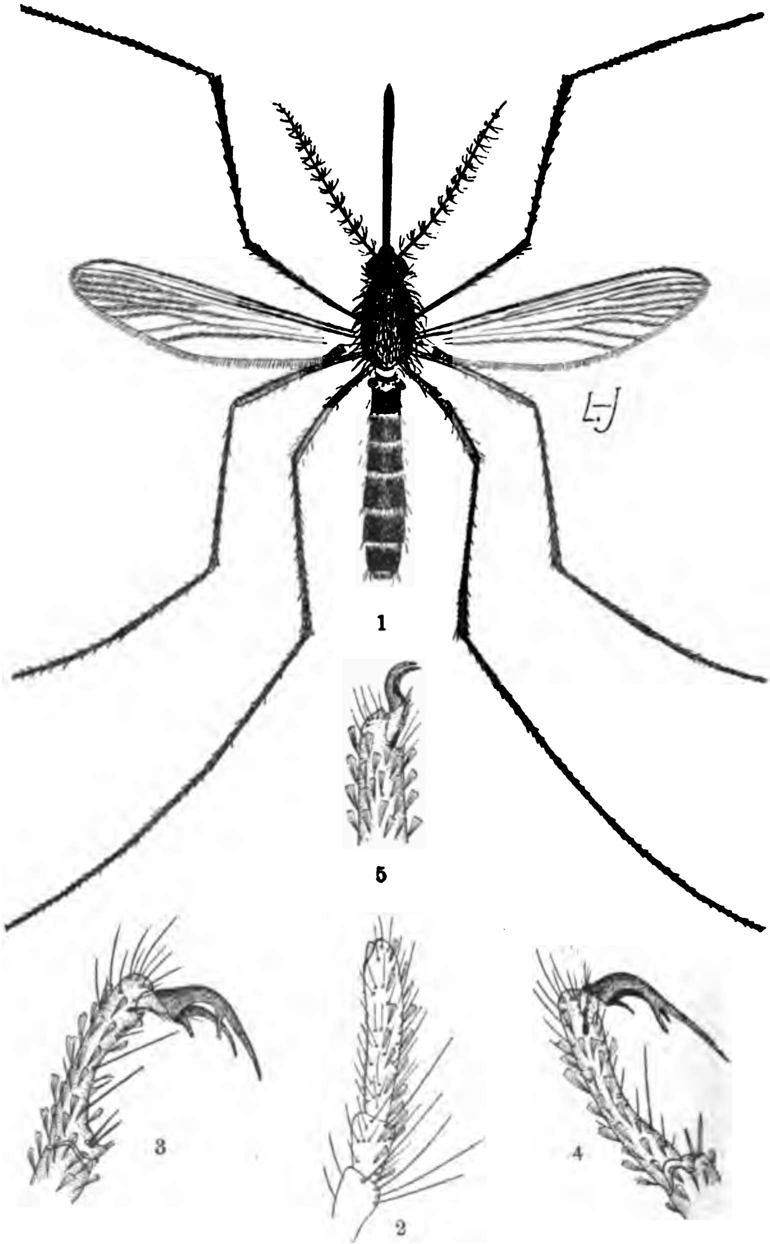

Figure 96.

Culex pipiens: 1, adult female; 2, her palpus, 3, anterior, 4, middle; 5, posterior claws of male: all enlarged. (Original.)

The thorax is brown, with many golden brown scales scattered over the surface. When partially denuded it is seen to be ridged, and this gives the impression of dusky longitudinal lines.

The femora are brown, becoming darker distally until, at the apex, there is a distinct white spot; beneath they are pale yellow. The tibiæ are dark brown, paler beneath, with an ochraceous spot at the extreme apex. The tarsi are blackish brown their entire length. The claws of the anterior (figs. 95, 3) and mid (fig. 95, 4) tarsal joints of the male are one toothed, the long claw with a median tooth, the shorter one with a basal tooth. The posterior claws of the male (fig. 95, 5) and all those of the female are simple, of equal length and somewhat sharply curved.

The abdomen is blackish brown, with yellowish, moderate or narrow bands at the base of the segments. In the female the bands, especially in the anterior segments, become narrower laterally and are well defined, while in the male they become very wide close to the lateral borders and the apical segment is often wholly yellowish. They are not so well defined in the male as in the female. Beneath the abdomen is yellowish brown.

The range of variation in size is considerable and that in color is very decided. In the pines of South Jersey the specimens are often almost rusty red and so large that I at first suspected a different species. Late in the season a small, almost blackish form makes its appearance at New Brunswick; but it is equally as vicious as the larger forms. As a whole this mosquito is best distinguished by having no peculiar characters. It is just the common every day brown mosquito that gets into our rooms and bothers us at night. If it has any peculiarity at all it is that it usually has a lean and hungry appearance.

Habits of the Adult.

The term "house mosquito" is expressive of the most objectionable habit of the species—its persistent effort to get indoors. Other species of *Culex* will get into houses through open doors or windows, or on the clothing of persons coming in; but *pipiens* actually works its way in through crevices, behind windows and even through screens. It comes indoors because it wants to and not necessarily in search of food. It should be explained that this is the species for which the term *pungens* is employed in some earlier writings. Recent study has developed the fact that our species is identical with the common European species and the older name takes priority. Dr. Howard has, indeed, suggested that this may be an importation from some

European country; but whether that be so or not, certain it is that the species is very much at home with us at present.

It winters in the adult stage and almost any place will serve, provided it is dark and sheltered from direct winds. Barns, cellars and the ordinary outbuildings are favorite localities, and I doubt if there is a cellar or dark basement in any mosquito ridden district which does not carry over its quota of hibernating females. The question of mosquito cellars and how they may be dealt with is treated elsewhere in this report. The astonishing thing is, in some cases, how so many specimens find their way into places to which there is often no direct entrance and where the openings for light are kept habitually closed. Hibernation begins long before breeding ends and some specimens of the early September developments go into retreat, to be joined by ever-increasing numbers from every succeeding brood. It has been indicated that only females hibernate, and these are impregnated before retiring; but they take no food, depending upon the stored products accumulated in the larval stage.

In the spring when warm weather has set in definitely these females make their way out, seek food and lay the eggs as soon as they are developed. No ovarian growth takes place in the hibernating specimens while they remain in winter quarters. Specimens were examined by Mr. Dickerson so long as any remained in the cellar of his home and in no case were the eggs at all enlarged in the ovaries.

When the eggs are developed, which is rarely until late in May, they are laid in the nearest suitable place, and almost any place where there is water of any kind will answer the purpose. The female oviposits at night or in the very early morning and from the description of an eye witness she rests on the surface with her legs extended, extrudes an egg from the ovipositor and places it broad end down on the surface, resting against the hind tarsi. The next egg is set against the one previously laid, and as it is coated with a sticky substance it adheres to it at once. And so egg after egg is placed until the boat is completed. When laid the eggs are nearly white, but they usually turn normally dark gray or brownish before morning. About 400 eggs are laid by one female; in one boat if she is undisturbed, in two or more if she is interrupted.

It usually requires only twenty-four hours or thereabouts for the larva to develop within the egg and hatch and hatching usually takes place at night, the little wriggler slipping out of the bottom directly into the water.

When the adults emerge during the summer the males usually appear a day or two before the females and copulation takes

place during flight in the early evening soon after the females have emerged. The eggs develop rapidly and in a very few days after assuming the adult form this summer mosquito is ready to oviposit.

This *Culex pipiens* is not a migratory form and flies no further than is necessary to secure food and a suitable place to lay eggs. As to the food, that matter has been discussed; for this species blood food is not necessary to enable it to mature ova. If the insect travels at all it is in search of a place to oviposit and there is no especial reason why it should not cover considerable territory in doing this. As a rule, where conditions favor its continued breeding the adults do not get far from the place where they matured.

As to the bite of this species it is not as painful as that of *sollicitans* or *cantator;* but it is apt to be more lasting. It feels somewhat as if the lancets were finer and more penetrating. *Pipiens* has the singing habit in an aggravated form and will hover a long time before deciding upon a satisfactory place to settle. This singing is actually more annoying to many people than the bite itself, and the sound when it begins just as sleep approaches, compels attention and effectually awakens the victim.

The number of broods is indefinite, and depends altogether upon breeding possibilities. In my pails I have at almost all times all stages from egg to pupa and the same condition of affairs may usually be found in any of the more permanent pools. In a rain-water puddle matters are different and all the larvæ will be of about one size.

The species occurs throughout the State, more or less abundantly as opportunities for breeding present themselves. Some localities that are usually quite free may, after a week or two of showery weather, become seriously infested.

Next to the salt marsh species this is the most offensive and troublesome mosquito in the State and, indeed in many parts of the State it is the only troublesome species. Hence it has been studied more fully and is here dealt with in greater detail than most other species.

Description of the Larva.

The larva is shown on figure 96a with details of structure greatly enlarged. When full grown it is 7–8 mm., = .28–.32 of an inch in length exclusive of the anal siphon. It is very transparent, pale yellowish in color and usually attains a faint shade of the color of the food eaten. Newly hatched and medium sized larvæ are almost white

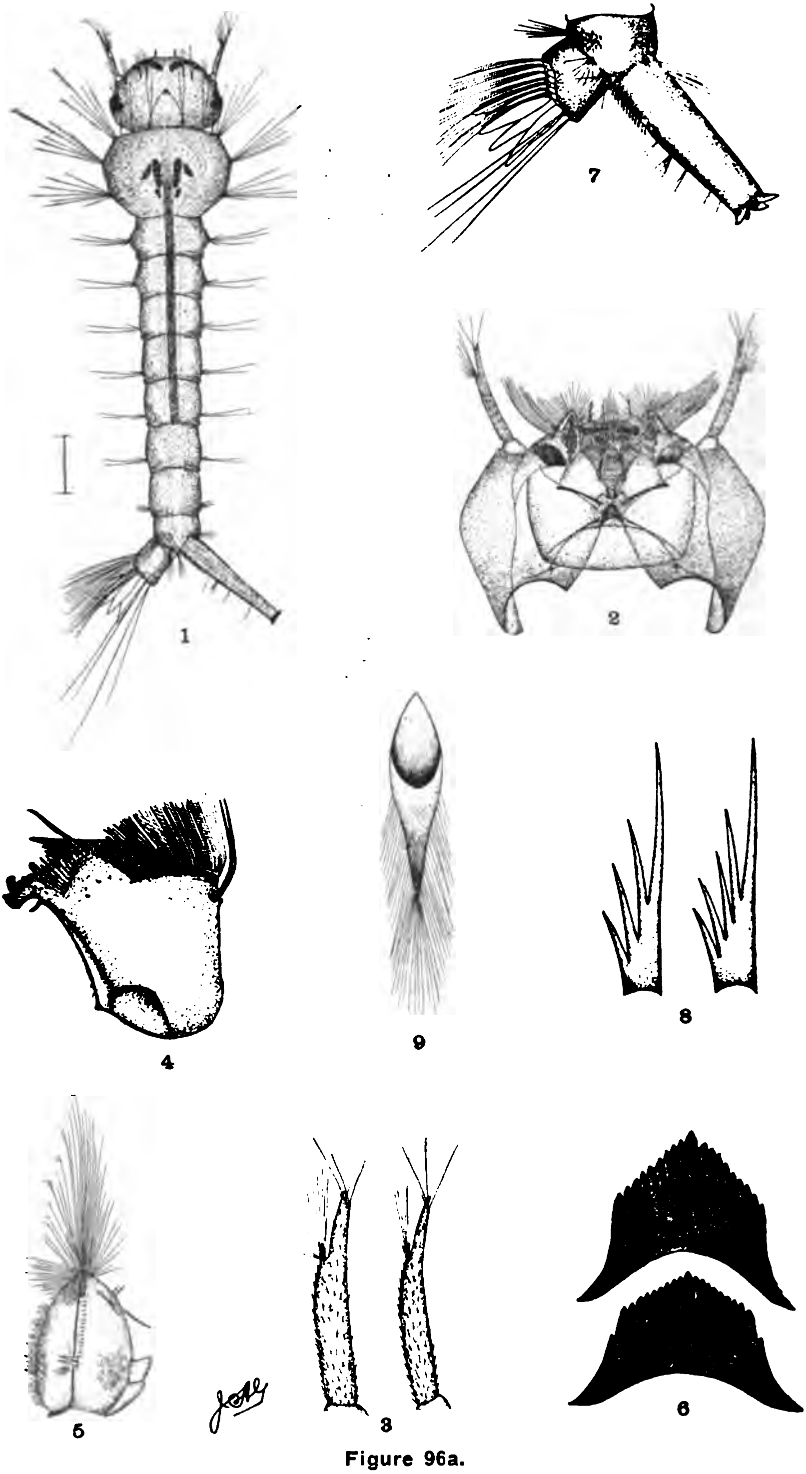

Figure 96a.

Culex pipiens: 1, larva; 2, head beneath; 3, antenna; 4, mandible; 5, palpus; 6, mentum; 7, terminal segments with siphon; 8, siphonal spines; 9, single scale from 8th abdominal segment: all enlarged. (Original.)

except for the food matter in the alimentary canal, and the yellowish tinge to the head and anal siphon. The head is transversely elliptical, full at the sides and pale fuscous in color; the maculation on the vertex is slight and consists of a central spot and two oblong marks at the sides more or less diffused. There are six tufts of moderately long hair of four or five hairs each on the dorsal part, the lateral ones near the base of the antennæ. The antenna (fig. 96, 3) is only slightly curved, completely infuscated and with a tuft of twenty or more long hairs arising from a sharp offset at the outer two-thirds. The surface is covered with short, spiny hairs and the apex has three long bristles, a short one, and a small joint. The eyes are large, there being two distinct forms—one in which they are blunt at the vertex and another in which they are drawn into an acute angle. The hairs of the rotary mouth brushes are simple. The mentum (fig. 96,6) is pentagonal in form, with nine or eleven teeth on each side of the apex; there is some variation, chiefly in the length from base to apex and the consequent slope of the sides. The mandible is best described by referring to figure 96, 4. The maxillary palpus (fig. 96, 5) is oval in shape with a long apical tuft and patches of short hair on the surface. The basal joint is small and is crowned with small spines at its apex.

The thorax in full-grown larvæ is rounder, broader than long, with scarcely any angulations. In the central part of the anterior margin are two tufts of long hair which extend forward over the head, and between these and the lateral tufts is another smaller one. A few single hairs of the first lateral tuft also encroach upon the anterior margin. In small larvæ the thorax is not so robust and the lateral angles are much better marked. The abdominal segments from one to seven have lateral tufts of two hairs each, except the two anterior ones, which have four or five hairs each, and pairs of smaller and finer hairs are scattered over the dorsal surface. The eighth segment has lateral patches of small scales from thirty-five to forty in number, the individual scales with long fringes at the sides and apex. The anal siphon (fig. 96, 7) is pale brown, about four times as long as broad and tapered on the terminal half. It has two rows of spines from twelve to fifteen in each series and a number of hairs arranged in pairs. The single spines (fig. 96, 8) are pale brown, broad at the base and with three or four long teeth. The ninth segment is completely covered with the chitinized saddle and the double dorsal tuft is composed of long hairs only. The ventral row of tufts is normal and confined to the barred area. The anal gills are longer than the ninth segment and rather stout. The

larva varies somewhat in the length of the anal siphon and of the anal gills, but not enough to be confusing.

Habits of the Early Stages.

This larva or wriggler may be found almost anywhere in stagnant water. There is no place so small and no water so foul as to bar this species. Anything from a tin can half full of rain water to a sewer basin, cesspool or manure pit will answer. Any pool of rain water that lasts eight or ten days, a bucket, a tub or other receptacle left outdoors, a rain barrel or even a watering trough that is rarely emptied will serve. In cities and towns the sewer basins form an important source of supply. Where there are no sewers, cesspools answer as well, and where rain barrels or cisterns are in use these are favorite breeding places. Neglected gutters in the outskirts of a city or town, sunken lots in which water accumulates, ditches along the roads when allowed to become overgrown and to become choked—all these are prolific sources of supply. And they will breed indoors as well as out if they are given a chance. I have found a brood in a battery jar left half filled with water in the laboratory, and have seen wrigglers in the concave floor below a shower bath which had become filled because of a plug in the waste pipe. In one of the leading seashore resorts many of the large hotels have a space from two to six feet below the basement floor in which pools form from surface drainage and in these pools larvæ develop in countless numbers. They find their way through the elevator shafts into the house and throughout the rooms to the great discomfort of the guests. I found by experience that I could leave my windows open safely at night, if only I closed the fanlight into the hall. It is this ability to develop almost anywhere that makes *Culex pipiens* our most common and widely distributed species.

After hatching from the egg as already described, the larva requires from six to eight days to attain full growth. The former is the minimum period in mid-summer when food is plentiful; the latter is the more usual period. When the weather is cold and the water clean it requires a longer period and the resulting adult tends to become dwarfed. The same effect is produced when a pool dries up so fast as to crowd the insects and force them into the pupal stage.

In the pupal stage the insects remain for two or three days, sometimes longer if the weather be cold. Rarely the entire development from egg to adult is crowded into one week.

Larvæ are rarely found until well along in May, and then only in comparatively small numbers. They do not become really common until July; but after that period and throughout August there is no suitable place where swarms of larvæ cannot be found. They continue in decreasing numbers after September until hard frost. I have found some of them under quarter-inch ice in November and bred adults from them.

There is nothing in any way peculiar in this larva or its development: it is typical in habit, entirely dependent upon the outer air for its supply of oxygen and succumbs readily to any oily covering of its breeding place.

The question of remedial measures is elsewhere taken up at length.

CULEX RESTUANS, THEOB.

The White Dotted Mosquito.

This species is closely related to *pipiens* in structure and habits, and without the aid of a lens no differences can be observed. The point of discrimination lies in the thorax; this has two or four small white spots on the upper surface and sometimes a U-shaped mark near the base.

Description of the Adult.

This mosquito runs about the size of *C. pipiens,* though in general it is smaller. The head is brown, with scattered yellow scales, and there is a yellow border to the eyes. The proboscis, antennæ and palpi of the male are fuscous; the palpi whitish beneath at the bases of the apical joints. In the female the palpi are dark brown, grayish at the apex, the fourth joint being shorter and retracted; the antennæ and proboscis are also dark brown.

The thorax is brown, with many scattered yellow scales over the surface and two or three equally spaced stripes of black bristles down the center. Two white spots on the middle of the dorsum are almost always present; two other patches of white are often situated more laterally and posterior of the spots, and an inverted U broken at the middle, near the base. The femora and tibiæ are brown, lighter beneath and at the basal part of the femora; the knees are distinctly white and the tarsi blackish throughout. The claws are the same as in *C. pipiens;* the anterior and mid unequal and one toothed, the posterior and all those of the female equal and simple.

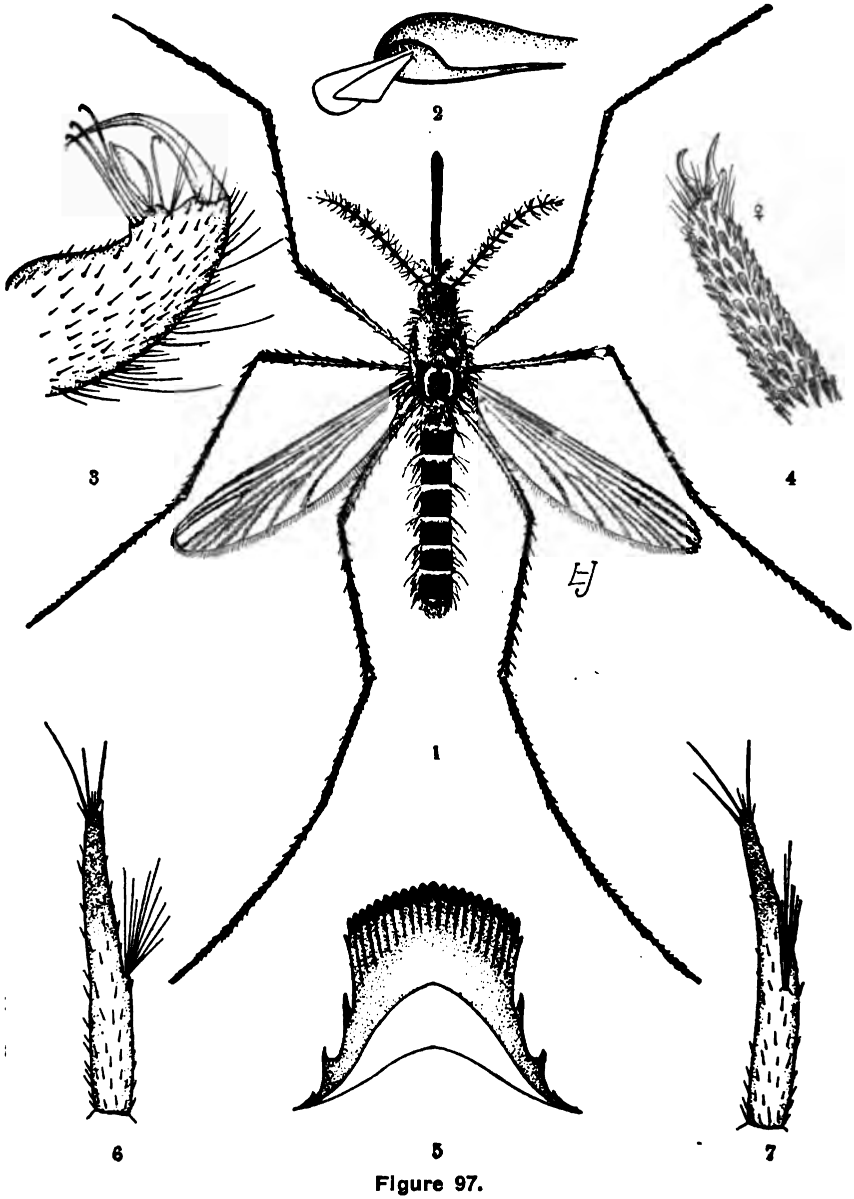

Figure 97.

Culex restuans: 1, adult female; 2, appendage to tip of clasper; 3, clasper of male genitalia; 4, anterior claws of female; 5, mentum of larva; 6, 7, antenna of same: all enlarged. (Original.)

The abdomen is blackish brown, with the pale yellowish bands narrow in the female and broader in the male.

Habits of the Adult.

The habits of this species are practically like those of *pipiens.* It winters in the same way and under the same conditions; its biting methods are much the same, and, in fact, so far as the adult is concerned everything that has been said of *pipiens* applies to this form as well. It seems to occur throughout the State, but is not quite so common as its better know ally. When the specimens are rubbed or have been in alcohol, there is no way of determining them positively as distinct from *pipiens.*

Description of the Larva.

In general apearance this larva resembles *Culex pipiens* so closely that the figure on page 310 serves for both species; some of the details, however, depart so widely from that species that it is at once recognizable. It differs from *C. pipiens* as follows: Antenna (fig. 97, 6 and 7) pale brown, whitish at the basal half with the tuft well below the middle; the hairs composing the tuft are shorter, only ten to fifteen in number, and are situated on a comparatively small offset. The surface is covered with hair-like spines and the apex is one long and two shorter spines, a few short hairs and a small joint. The mentum (fig. 97, 5) is peculiarly shaped, almost square in form, rounded at the apical margin and excavated inwardly at the base. Each side has three or four teeth, the central ones largest; the anterior margin has from seventeen to twenty-three small, evenly shaped teeth. The anal siphon is similar to that of *C. pipiens,* both species varying in length somewhat; but there are a few more spines to the lateral row in *restuans.* The anal gills are long, not pointed and with circular spots scattered over the surface.

Habits of the Early Stages.

Eggs are as in *pipiens,* to all appearance. Both species occur in my pails and I have frequently examined the egg boats to determine, if possible, whether any superficial differences exist, but have never found any. In general appearance and habits the larvæ are also similar; but *restuans* is not found in really foul water, in my experience. In life the two species are readily discriminated by the antennæ, which are always prominently spread out, so that the position of the tuft is readily noted. The wrig-

glers occur in the pails quite as early as those of *pipiens*, and Mr. Brakeley has found them in the water in an ornamental vase at Lahaway in October.

CULEX SALINARIUS, COQ.

The Unbanded Salt Marsh Mosquito.

This species is so like *C. pipiens*, the ordinary house or rain barrel mosquito, that the description of the latter will apply to the present form. In all structural details save the tip of the female palpi, the drawings for the one will answer for the other as well. *Salinarius*, however, which was called *nigritulus* in my earlier papers, is somewhat slighter in build, giving the legs an appearance of unusual length. In the female the white bands of the abdomen are narrower and better defined, while, as a whole, the mosquito seems blacker in color. In a long series of adults from various localities the lanky and generally darker appearance would form the best characters for their separation. If the specimens are a little rubbed or in alcohol, there is no distinguishing them.

Habits of the Adult.

This is the only one of the salt marsh mosquitoes that does not migrate for any considerable distance, and the only one of them that hibernates in the adult stage. It seems much more abundant on the Newark and Elizabeth marshes than it does further south, and at Cape May it was not found by Mr. Viereck until well along in the season. It is a night flier and, on the marshes where *sollicitans* and *cantator* rise up to greet the visitor, *nigritulus* will not be seen at all. But in the early evening it flies readily and is as greedy for blood as any other of the species. It sings like *pipiens* and has the same tendency to get into houses, though perhaps not so well marked. Hibernating specimens have been found by Mr. Brehme in buildings along the edge of the marshes, and it is quite possible that the insects come up into the edge of the cities even though they fly no further inland. They remain in hibernation until April and continue breeding until October.

Mr. Viereck observed their marriage flight at Cape May on two occasions, just at nightfall. An egg boat is formed as in case of *pipiens* and *restuans*, but the aggregation of eggs is smaller in number.

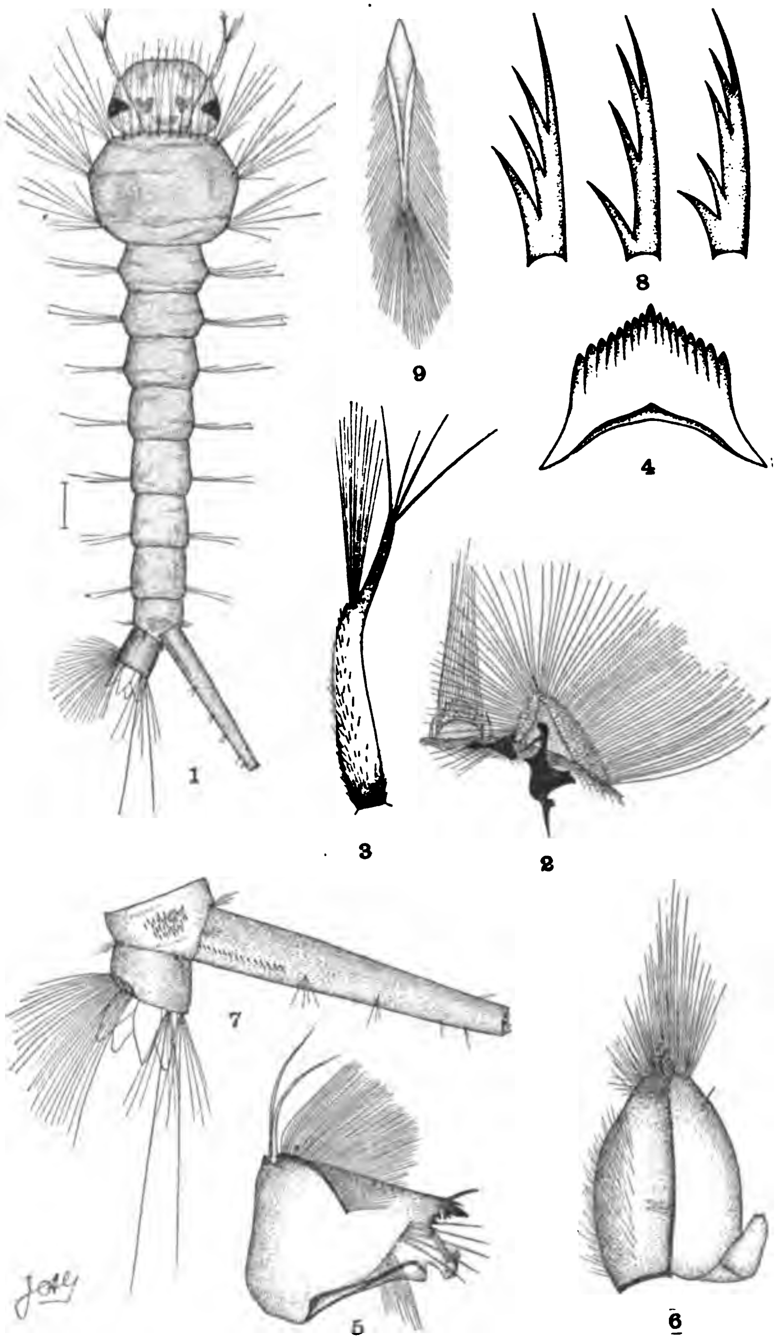

Figure 98.

Culex salinarius: 1, larva; 2, mouth brush; 3, antenna; 4, mentum; 5, mandible; 6, palpus; 7, terminal segments and siphon; 8, siphonal spines showing variation; 9, a single scale from 8th abdominal segment: all much enlarged. (Original.)

Description of the Larva.

The larva, with details, is illustrated on plate 98. When full-grown it measures 6–7 mm.,=.24–.28 of an inch in length, exclusive of the anal siphon. When young, the wrigglers are whitish in color with a tinge of yellow or brown, and the head and thorax are very large in comparison with the abdomen. Large larvæ are translucent, pale yellow or brownish with the regions of the body proportionate. The head is sub-quadrate, broadest through the eyes, about one and one-half times as long as broad. Prior to the last larval stage it is larger than the thorax, and usually immaculate; in the last stage, however, it is smaller than the thorax, more chitinized and with blotches on the vertex which, though variously shaped and diffused, are always bi-symmetrical. Near the anterior part of the head are four tufts, each composed of four or five hairs, and a somewhat larger tuft at the base of each antenna. The antenna is large and long, thickest near the base, tapering slightly for two-thirds its length, then becoming abruptly very narrow to the apex, leaving an offset upon which is a large tuft of long hairs extending considerably beyond the tip. The apex with three long bristles, a shorter one, and a small articulated joint. In color it is white, black at the apical third and at the base, the surface covered with fine hair-like spines. The eyes are large, black and occupy the broadest part of the head. The rotary mouth brushes (fig. 98, 2) are entirely composed of simple hairs. The mentum (fig. 98, 4) is pentagonal in form, with fifteen to twenty-one teeth, always with an equal number on each side of the apical tooth. The mandible (fig. 98, 5) is triangular in shape with blunt corners. The maxillary palpus (fig. 98, 6) has a rather small tuft at the apex; the surface is clothed with patches of hair and the basal joint is very small. The thorax is wider than long, the angles very acute in small and half-grown larvæ. Beside the normal lateral hairs, four small tufts of two or three long hairs each, extending forward over the head are on the anterior margin, and several smaller tufts are between these and the first lateral tuft.

The abdominal segments from one to six are subquadrate in form, deeply constricted at the joints, especially in the anterior segments. There are two hairs to the lateral tuft in all except the first and second segments, these with three or four hairs; smaller tuft hairs of very fine hairs are also on the dorsal part of the segments near the lateral borders. The seventh segment

has only the short hair tufts. The scales of the lateral patches on the eighth segment are small, from twenty-eight to fifty in each patch, irregularly arranged. The single scale has long fringes at the sides and apex, as shown in figure 98, 9. The anal siphon (fig. 98, 7) is long and slender, not concave, evenly tapered, varying in length from five to seven times its width at the base. There are from twelve to eighteen spines in each lateral row, extending about one-third from the base, the individual spines are broad and light-colored, with three or four teeth each; a small short tuft terminates each row and there are several smaller ones toward the apex. The ninth segment is slightly longer than broad, with the hairs in the ventral row of tufts rather short and the double dorsal tuft mostly with very long hairs.

Habits of the Early Stages.

The egg boats of this species seem to disintegrate rapidly and are rarely found. The larvæ occur everywhere on the marsh in salt as well as fresh water, but as a rule they are more abundant along the edges of the highland than nearer the shore. No specimens have been collected prior to the last days of May, though as they were then two-thirds grown, it is probable that the middle of May is about the date of their first appearance. They increase in numbers as the season advances and continue until late October. Ordinarily they are found in tolerably clean water and when in company with the stumpy tailed wrigglers of the other marsh species they are readily recognized.

CULEX MELANURUS, COQ.

The Black-tailed Mosquito.

This is a rather small mosquito, dark brown in color, with legs and beak unbanded. The wings are unspotted and the segments of the abdomen have the merest indications of white bands at their base.

Description of the Adult.

This small mosquito could easily be taken for *C. pipiens,* especially if the latter were worn so as to render the banding obscure; it is, however, smaller and of a richer brown color. The body, exclusive of the beak, measures 4–5 mm., or about

.16–.20 of an inch in length; the beak is three-fifths the length of the body and across the wings it averages about 8 mm., or .32 of an inch. The anterior part of the head is taken up by the

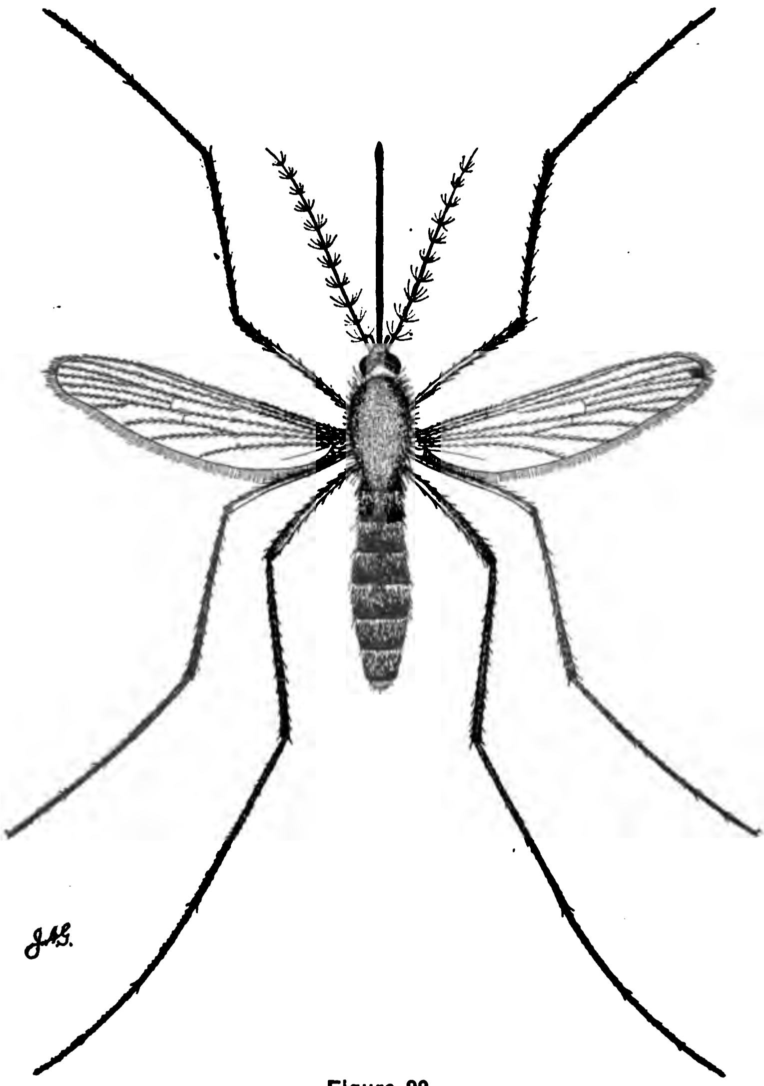

Figure 99.

Culex melanurus: female adult: enlarged. (Original.)

large black eyes and the occiput is covered with white scales. The palpi in the female (fig. 100, 4) are short, four-jointed and set with rather long hair; the terminal joint is reduced to an

extremely small circular knob, slightly retracted within the third joint. The male palpi (fig. 41, 5) are a little longer than the beak, not dilated, the basal joint with a slight angulation just before the middle; color brown, with the terminal joint white at the base. The fan-like tufts toward the tip though long are not dense. The antenna of the male is plumose, longer than the basal segments of the palpus, the two terminal joints long and slender, others cup-shaped, with the usual circle of long silky hairs. The female antenna is slightly longer than the beak, joints of uniform lengths, brown, white at the base, set with rather short stiff hair over the surface and with a circle of long bristles at the base of each.

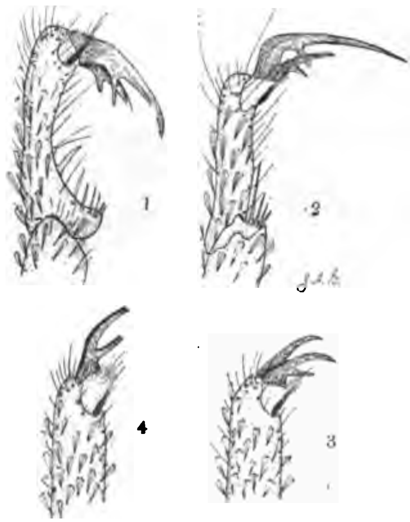

Figure 100.

Culex melanurus: 1, anterior; 2, middle, 3, posterior claws of the male; 4, palpus of female: all much enlarged. (Original.)

The thorax is evenly brown, covered with very short spiny hair. The legs are dark brown, with the under side of the femora yellowish white. In the male the inner claw of the anterior tarsal joint is long, with a median and basal tooth; the outer claw is smaller and has only a single tooth near the base. The claws of the mid tarsal joints are much the same, except that they are a little longer and more slender, while the claws of the hind tarsal joints are simple. In the female the claws are alike on all feet, being the same as the posterior ones of the male.

The abdomen is dark brown, very narrowly banded with

yellowish white at the base of the segments. Sometimes the bands are obsolete and sometimes, on the more anterior segments, divided in the center by the brown. Beneath the color is ashen gray in the females, but darker in the males.

Habits of the Adult.

Practically nothing is known of the habits of the adult; but it is reasonably certain that the species does not bite. It must be fairly abundant at Lahaway in May, but Mr. Brakeley has never taken it either in his room captures or in the field, day or night. No specimens have been taken by any of the collectors in their general gatherings, so the species must be a very local one in New Jersey. It certainly does not rank as a troublesome or pestiferous one.

In general appearance it resembles an undersized, dark *pipiens* and would not be readily distinguishable from it did the two fly together.

Description of the Larva.

The larva is illustrated on figure 101, with details of structure greatly enlarged. When full grown it measures, exclusive of anal siphon, 7–8½ mm.,=.28–34 of an inch in length, is of a delicate build and of a pale yellowish or bronzed grayish color. The head is yellowish brown and the siphon dark brown, black toward the tip, rendering it rather conspicuous in contrast with the paler color of the larva. The head is large, almost the size of the thorax, is not quite three-fourths as long as broad, rounded in front and full at the sides, with a decided offset between the vertex and the genæ for the reception of the antennæ. The vertex is immaculate, with two small hair tufts near the center and one long hair slightly in advance of each; another tuft is at the base of each antenna. The antennæ (fig. 101, 5) are long and slender, narrower beyond the tuft, curved inwardly, uniformly grayish brown, with the surface covered with long spines. The tuft is large, composed of many long hairs and arises from an offset at the outer fourth; the apex with three very long bristle-like hairs, one short bristle and a very small terminal joint, all articulated. The eyes are reniform, not large and are situated on the sides where the head is widest; sometimes the eye is divided into two parts, one large anterior body and a little one at its center, posteriorly. The hairs composing the rotary mouth brushes (fig. 101, 3) are long and silky, and are not

pectinated. There is very little variation in the mentum and it is usually two and one-half times as broad as long, as shown in figure 101, 6. There are from seven to nine large teeth on each side of the apex (eight being the average), which have a tendency to point toward the centre. The mandible (fig. 101, 9) is triangular, rounded at the corners, the dorsal part with three long, curved spines and a number of short ones, the outer part of the base with a patch of fine hair-like spines. The maxillary palpus (fig. 101, 4) has a moderate tuft of long hair on the apex and a number of pectinated hairs on the base. The basal joint is very small, with four spines at the apex.

The thorax is angulated but slightly, transversely oblong and with numerous hairs arising from tubercles at the angles of the sides; the anterior margin has some very long stout hairs extending beyond the head, the most central ones being grouped at the base, but issuing from separate tubercles, the more lateral ones separated at the base, each with one or two hairs.

The abdominal segments from 1 to 7 are subquadrate in form, the anterior two with lateral tufts of four or five hairs each, the following four with tufts of two hairs, while those of the seventh and eighth are very much reduced. The scales composing the combs of the eighth segment are greatly elongated (fig. 101, 8) from seventeen to twenty-six in number, arranged in a single row, as in figure 101, 2. The anal siphon is five or six times as long as broad, tapering slightly toward the apex, dark brown, black tipped, with a double row of very small, simple or one-toothed spines, eleven to fifteen in each row. On the ventral border there is a row of about thirteen small, fine-haired tufts extending its entire length. The ninth segment is considerably longer than wide, with the ten or twelve tufts on the dorsal part of the apical margin also short, each with one very long hair. The anal gills are as long or nearly as long as the ninth segment.

Habits of the Early Stages.

From time to time Mr. Brakeley had mentioned in his letters a "bronze wriggler" which occurred in woodland springs, very late in the season, specimens being taken up to the middle of November; but no attempt was made to breed it until, after a specimen had been sent to Dr. Dyar, who pronounced it *melanurus,* a species originally taken by him in New Hampshire. In the winter of 1902–'03 Mr. Brakeley determined to test his belief that these larvæ hibernated in that condition and found that there were several places on his land where they could be found

other than the springs, nearly or quite all of which had a greater or smaller supply. The chief point of interest was a stretch of swampy bog land that had been burnt over early in 1902, the fire eating through the moss in places and leaving a mass of irregular holes, varying in size and depth. Some of these were partly closed by vegetation covering in from the edges and making an overhang. The ground was springy and there were numerous springs round the edges, so that the water was always cold and usually clear; but with a flocculent sediment which was readily stirred up.

January 9, 1903, with the thermometer 9 degrees above zero, the entire swamp was frozen solid. January 23d broke the ice on likely pools and made about a dozen dips in as many places. Nothing was found and the inference is that the insects shelter either in the mud or under the overhanging vegetation. January 30th, during a mild spell, collections were made in pools from which the ice had just disappeared, and now quite a little series of specimens was obtained, some of them inactive and apparently dead, but all revived when brought indoors. On the 31st, covered another part of the same territory and found specimens everywhere: "Little holes, not over two inches in diameter, full of water, turned out two or three specimens." February 1st, collected additional specimens and brought in some of the ice to see whether larvæ were frozen in it. Found that there were none and that the specimens probably kept down below actual frost, if possible. February 7th, it was noted that there was considerable difference between the larvæ, as though two or more stages were represented, and, as a whole, they were more advanced than in December; in the larger specimens a distinct shield-like form of the thorax was now apparent. Collections were made throughout February, and the indoor cultures were under constant observation; but though the larvæ seemed to feed continually they did not grow and spent most of the time at the bottom of the jars: they do not need air from above the surface. On February 22d, when the ground was snow covered and everything frozen over, holes were made in the ice and active larvæ were dipped up from beneath it. The water here was 36 degrees, and in the woodland springs where other specimens were taken it ran 42 degrees. Rain and snow so filled the swamp area that the wrigglers were scattered over so large a territory it was almost impossible to find them. At this time a series of the specimens was sent to me to be developed in the laboratory, and these arrived in good condition. Throughout March collections were made, and during this time it became so dry that it seemed as if all the larvæ must have perished: yet after a

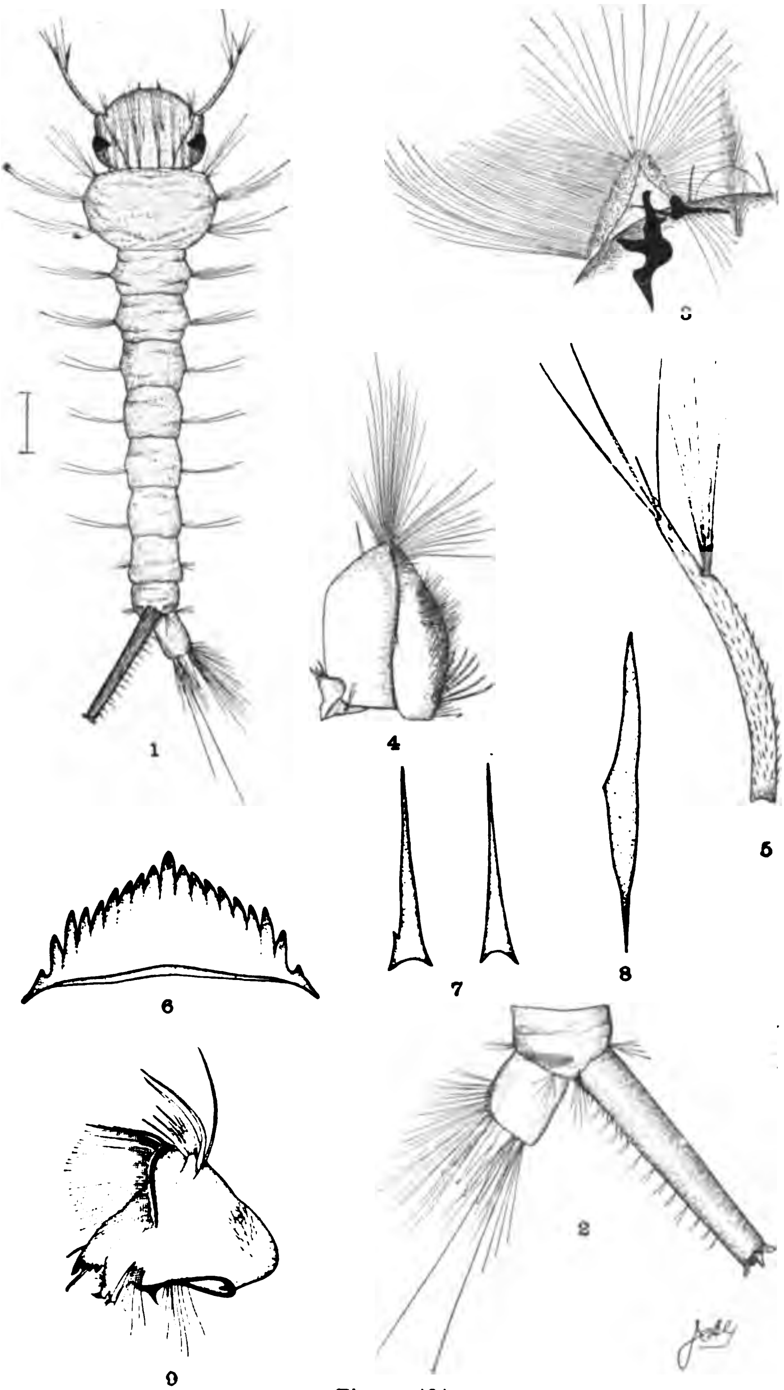

Figure 101.

Culex melanurus: 1, larva; 2, terminal segments with siphon; 3, mouth brushes; 4, maxillary palpus; 5, antenna; 6, mentum; 7, siphonal spines; 8, scale from 8th segment; 9, mandible: all much enlarged. (Original.)

rain there were as many as ever. They seem able, apparently, to seek out the wettest places and may even survive for a time in soft mud. April 2d and 3d, collected another lot of over 100 larvæ for shipment to me, and up to that time there had been no pupa seen. The first specimen in the culture material pupated April 4th, and as I obtained the first pupa just a day earlier, this may be considered the beginning of the pupation period. The pupa is small in proportion to the size of the larva and the period of this stage is from six to ten days. The last larvæ were collected by Mr. Brakeley May 5th, and in nature only one pupa was taken—an accidental mingled with *canadensis.*

This record of collections made is an interesting one and proves positively that the larva of *C. melanurus* lives through the winter in the half-grown condition. It is essentially a clean-water wriggler and requires a sheltered locality, like woodland, or an over-grown swamp area, to develop. An area that freezes solid would probably prove fatal, but in spring-water the temperature rarely gets much below 40 degrees, even in the coldest weather, and when there is an ice-covering in the swamp there are the recesses under the edges and the deep, soft mud to serve as retreats. I have no record of the re-occurrence of this larva in the springs before October, and none of the summer collections sent in by Mr. Brakeley contained specimens. Nor have I seen any very small larvæ or eggs.

A characteristic feature of the species is its remarkably slow growth in spring and the long delay in pupation. The larvæ are half grown, or more, before *canadensis,* or *aurifer,* are born, yet the latter become adult as soon, or sooner. They are slow in their movements and seem to take life easy, "like a group of dreamy philosophers," as Mr. Brakeley puts it. They are bottom-feeders of necessity, since the water in which they live has only a small supply of organic life, but in the leaves at the bottom of the springs and in the mud of the swamp pools their food is found. So they have well developed trachea in the anal gills and are not dependent upon atmospheric air for their supply of oxygen. This peculiarity is also essential, as their swamp breeding places may and do become completely ice-covered.

As to the egg-laying habits, nothing is known to me. They are probably laid on the surface and may, or may not, sink to the bottom before hatching.

CULEX TERRITANS, WLK.

The Little Black Mosquito.

This is a small black mosquito with long, unbanded legs and beak and unspotted wings. The abdomen is narrowly banded

with white at the apex of the segments. This character occurs only in one other of our species, *C. discolor,* and that has spotted wings.

Description of the Adult.

This is one of the smallest species of the genus *Culex,* and a very delicate looking mosquito. In length it is 4.5–7 mm., = .18–.20 of an inch, exclusive of the beak, which is 2 mm. long. The head is dark brown with scattered whitish scales; the proboscis is brown, darker toward the apex, without marks or rings.

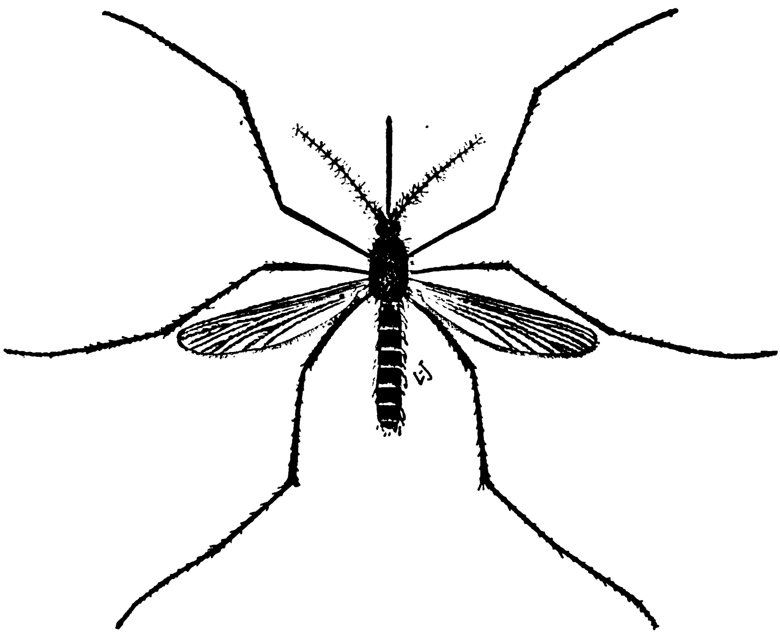

Figure 102.

Culex territans: adult female: enlarged. (Original.)

The palpi in the female are brown, shape and position of terminal joint as in *C. pipiens*, save that the third joint is swollen toward the tip. In the male the palpi are blackish, the basal joint almost reaching the tip of the proboscis, the two terminal ones short, the apical slightly shorter than the central one. They are slender in form, not dilated, precisely as in *C. melanurus,* the figure of which answers perfectly for *territans*. The antennæ of both sexes are brown, the plumes of the male paler.

The thorax is evenly brown without spiny clothing, though the sides are fringed with long, black, curved hairs. The pleura

are brown with patches of grayish white scales. The femora and tibiæ are very dark brown, their apices with a white spot and the under sides wholly creamy white. The tarsi are all black without rings or bands. The claws in both sexes agree with those of *C. pipiens,* being equal and simple in the female and in the posterior tarsi of the male, while those of the mid and anterior pairs of the male are unequal in length with a single tooth to each claw.

The anterior is blackish brown, with narrow apical bands of white, which become wide at the sides, until, beneath, it is wholly white or grayish white.

Habits of the Adult.

Little is known of the habits of this species, though it is by no means uncommon. It is not certain even that it bites, although until recently I have believed that it did. I had identified this species with that little black mosquito that sometimes in mid or late summer seems perfectly frantic in its attempts to get indoors, and works through the meshes of the ordinary wire screen without apparent difficulty. I am not certain now that this form is not really an undersized brood of *pipiens,* forced to develop prematurely by the drying out of the breeding pools. At all events, even if the species is really guilty, its attacks are infrequent and not of long duration.

It is not definitely known how the insect hibernates, though the indication is that it does so in the egg stage. It is certain that none of the collections of hibernating adults thus far made has produced even a single example of this species. *Territans* is not uncommon at Lahaway, yet in Mr. Brakeley's thorough collections in the cellars and outbuildings there it did not occur once. It is also quite common at Bordentown; yet among the hundreds of mosquitoes taken there in cellars and empty houses by Mr. Brakeley not an example of this form was found. In fact, none of my collectors ever found any specimens in winter.

Among the house collections *territans* occurs rarely, and Mr. Brakeley reports only one specimen, July 26, 1903, in the dining-room at Lahaway. Practically no specimens were in the extensive series of collections made for me by Mr. Buchholz at Elizabeth in 1902 and 1903. In reality, there were 13 examples out of 318 that seemed referable to this species in the 1902 collection. The collections made in 1903 show an even smaller percentage in a much greater number of examples, all taken late in the season. There is some doubt also about the egg-laying habits

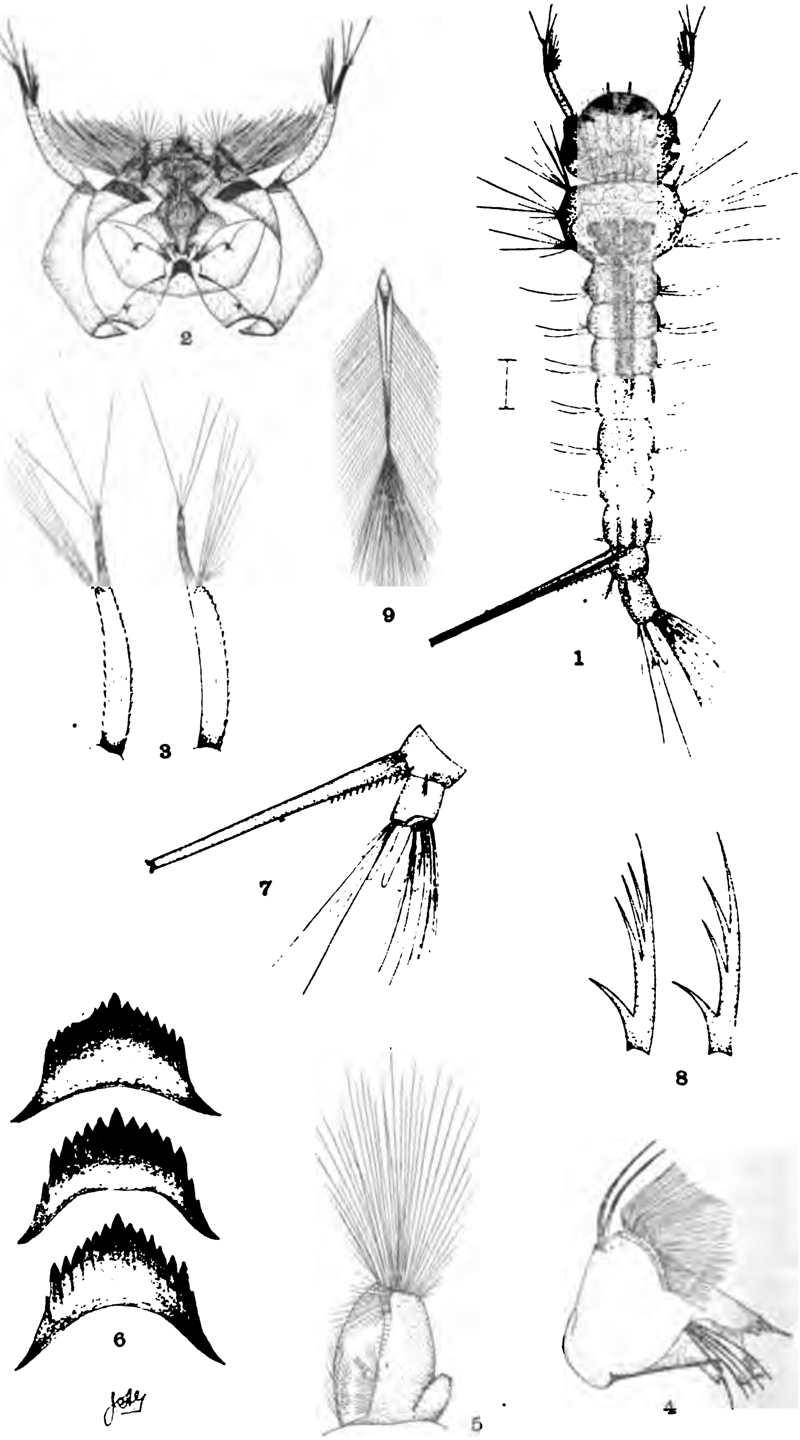

Figure 103.

Culex territans: 1, larva; 2, head from beneath; 3, antenna; 4, mandible; 5, palpus; 6, variations in the mentum; 7, terminal segments with siphon; 8, siphonal spines; 9, a single scale from 8th segment: all much enlarged. (Original.)

of the insect, but it seems certain that it makes small boats which probably disintegrate rapidly, allowing the individual eggs to sink to the bottom.

Territans is not a traveler, and seems very local, even where it occurs in considerable numbers.

Description of the Larva.

The larva (Plate fig. 103, fig. 1) when full grown measures 6–7 mm.,=.24–.28 of an inch in length to the tip of the ninth segment. It is slenderly built, of a whitish or dirty yellowish color, sometimes pale green, from the color of the food eaten. The head is very large in proportion to the rest of the body, subquadrate in form and about one and one-half times as broad as long. It is pale, creamy white in color, and totally immaculate; though the orange-colored mouth brushes, when retracted, give the impression of marks on the front of the head. On the anterior part of the vertex are four hair tufts, each with two long hairs, and there is a large tuft of 6 or 7 hairs at the base of each antenna. The eyes are comparatively small and occupy the widest part of the head. The antenna (fig. 3) is large, white in color, with the apical third and base back; it is broad two-thirds from the base, then, curving and becoming abruptly very narrow, there is formed an offset upon which is a large tuft of long hairs. The surface is covered with hair-like spines, and the apex has three long bristles, a very short one and a little joint. The rotary mouth brushes are composed of simple hairs, and are bright orange in color. The mandible (fig. 4) is triangular, without the usual row of long spines on the margin between the apex and the two large curved spines. The maxillary palpus (fig. 5) is pale, with long white hairs at the apex; the basal joint extremely small with rather large teeth at its tip. The mentum has 6 to 8 teeth on each side of the apical one, and in form is broadly pentagonal; but sometimes the teeth extend farther toward the base, cutting off the lateral angles and giving a more triangular shape as shown in the figures.

The thorax is somewhat smaller than the head, and has acutely angled lateral margins from which issue tufts of fine long hairs. There are eight other tufts on the anterior margin, the central two longest extending forward over the head.

The lateral margins of the abdominal segments are very nearly parallel with the exception of the anterior two, which have lateral prominences, giving rise to four hairs each, while the remaining segments have but two hairs to the lateral tuft. There are small

hairs at the base of each tuft, the seventh segment having the small tufts only. The eighth segment has a large patch of 25 to 50 extremely small elongated scales with long apical and lateral fringes (fig. 9). The anal siphon (fig. 7) is pale yellow, very long and slender, and, though slightly variable, is usually half as long as the larva from the base of the siphon to the head, inclusive. It is broadest at the base, slightly constricted centrally, and with two series of weak spines, from 10 to 14 in each series, extending one-third of its length from the base. These spines have from 3 to 4 long teeth, the apical two or three often crowding toward tip. There are 6 to 8 fine tufts on the ventral side between the terminating spine and the apex. The ninth segment is at least one and one-half times as long as broad, with the ventral brush composed of but 6 or 7 tufts of long hairs and a few short hairs below the barred area. The dorsal double tufts have one long hair each and several shorter ones. The anal gills are about as long as the ninth segment.

Habits of the Early Stages.

This is one of the few mosquito larva that is really recognizable at a glance; the large square head and the very long and very slender anal siphon forming a combination that cannot be mistaken. This is, essentially, a clean water wriggler, though it is occasionally found in stagnant water. Mr. Brakeley and Mr. Grossbeck both report it from rain barrels, each once only. It has occurred in my pails once only so far as our records go. Mr. Brakeley has a pool with cattails where specimens can usually be found until November, and I have taken it myself at the extreme edge of one of the fish ponds at Lahaway. The margin here was very shallow, the pine chats from the edge extending under water to some distance, and here specimens could be found in small numbers. Among the grass in a lily pond, also inhabited by fish, examples are also to be found at almost all times. In fact the grassy edge of large ponds is a favorite place for this species, which seems to escape fish better than most other wrigglers. Another favorite breeding place is in the quiet eddies or side pools of even rapid streams where it is usually the only species found. It is frequent in springs and is almost universal in swamp pools formed of spring water. It gets down to the edges of the salt marsh at times and is found in company with *salinarius* in the more permanent pools at the edge of the highland. In fact, this is essentially an inhabitant

of permanent water bodies and in swamps is the frequent companion of *Anopheles*. But it may be and is also found in pools which dry out completely at times, and even in rain pools and woodland depressions. It is not a universal breeder, however, like *pipiens,* and never occurs in such masses; the larvæ are individual in occurrence rather than in swarms.

No larvæ have been found by Mr. Brakeley in his winter collections, even in the pools in which they were found late in fall. In a lot of material sent in April 7th, 1903, *Aedes fuscus* and *Culex canadensis* were brought to maturity April 13th and 14th respectively, and when about everything was gone, April 19th, young larvæ of *territans* began to make their appearance, the eggs having been, without doubt, in the mass of sediment sent with the specimens. A similar experience with another lot of specimens makes it reasonably certain that the eggs winter at the bottom of the pools and ponds where the larvæ occur, but whether they will stand a winter drying out or not is a question. The larva is not an early one. Mr. Brakeley's record is May 12th for single specimens and as late as June 2d he records a "regular nest of *territans* apparently just hatched." None of our early collections turn out *territans* before the middle of May and it is not until the season is well advanced that they become at all plentiful. They hang on in fall, however, until November, and are among the last of the species to be found outdoors. Mr. Grossbeck took them in early October in a swampy area along the Passiac, both as full-grown larvæ and pupæ, from each of which forms adults were obtained later in the laboratory.

Mr. Brakeley took larvæ in a ditch spring October 27th, after it had been ice covered, but they were not brought to maturity. Pupæ were found in a spring that had been ice covered November 3d and adults emerged on the 7th. November 18th, another lot of larvæ was taken from an ice-covered pool, but these were not bred. Whether these late adults mate and oviposit is not known; that they perish soon after they are born is indicated by our failure to find any of them in winter quarters.

Taken as a whole, this can scarcely be counted among the really troublesome mosquitoes and that is fortunate, because it is one whose breeding areas it would be most difficult to control. No other *Culex* lives in water so shallow as this, and no other is an inhabitant of streams and ponds to the same extent. *Anopheles*, however, does occur with *territans* in most of its breeding places and any attempt to control the one would naturally affect the other.

AEDES FUSCUS, OSTEN-SACKEN.

The Little Smoky Mosquito.

A small dark brown mosquito with black unbanded legs and beak; the thorax is evenly brown, sometimes with faint longi-

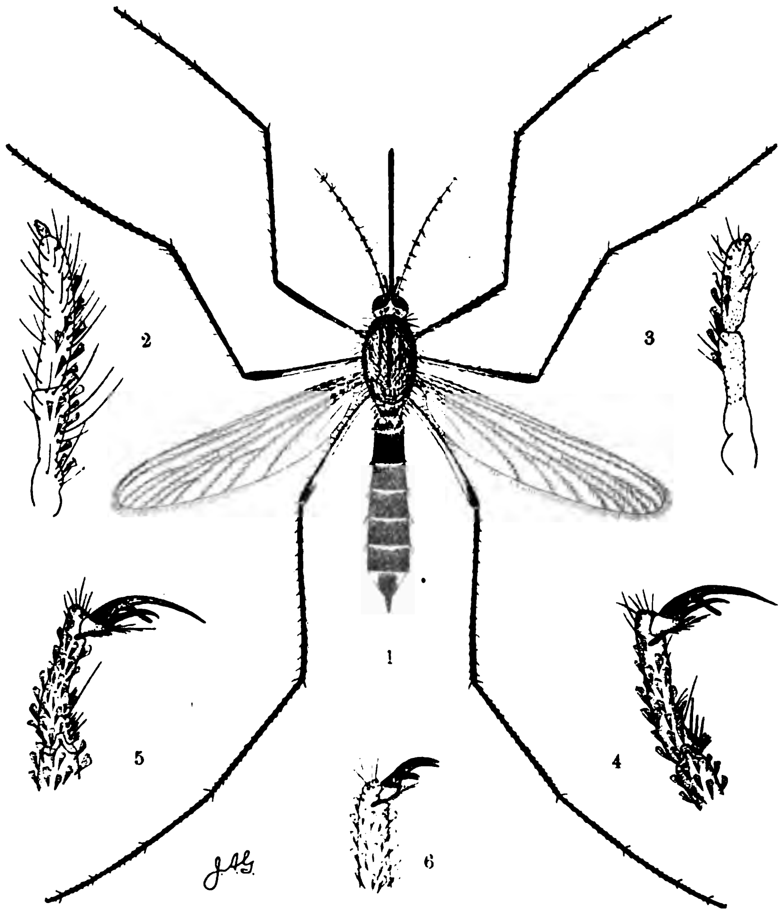

Figure 104.

Aedes fuscus: 1, female adult; 2, her palpus, 3, palpus of the male; 4, anterior; 5, middle, and, 6, posterior claws of the male: all much enlarged. (Original.)

tudinal black lines, and the abdomen is black, usually with narrow bands at the base of the segments, broadest in the central portion.

Description of the Adult.

This is a small mosquito, the body measuring 3.5–4 mm..= .14–.16 of an inch in length and the beak just about half the length of the body. The head is covered with creamy yellow scales; in the female there are two large patches of brown scales in the central part of the occiput converging anteriorly; in the male these patches are much reduced and widely separated. The proboscis is black without bands or rings. The palpi in the female (fig. 104, 2) are short, set with moderately long bristles, three jointed, the second joint longer than the first, and the terminal joint very small, though longer than broad and pointed at the apex. In the male the palpi (fig. 104, 3) are about three-fourths the length of those of the female, three jointed, the second joint shorter than the first, the terminal joint minute and circular in outline, first and second joints set with a few bristles toward the apex. The antennæ are dark brown in the female, with the three basal joints pale yellowish; the male antennæ are banded brown and white, the first joint very large, the second swollen, and the plumes brownish.

The thorax is evenly reddish brown, sometimes with one or more faint blackish lines down the center and the pleura are pale brown with small irregular patches of dirty white scales. The legs are wholly black, except the femora, which are creamy white beneath and with a very small white dot at the knee. The claws of the male anterior and mid tarsal joints (fig. 104, 4 and 5) are unequal in size, the larger with a long, blunt median tooth, the smaller simple. The male posterior claws (fig. 104, 6) and all those of the female are equal, rather slender and with a single median tooth near the base. The clothing and venation of the wings are similar to those of *Culex*, but the lateral scales are long and slender.

The abdomen is black, above, with narrow creamy basal bands; in the female these bands are wide in the center, becoming narrow toward the sides, save in the seventh segment, which usually has a narrow band, broad at the sides. In the male the bands are always wide, broadest at the extreme sides, often forming a lateral margin to the apical segments. Sometimes the basal bands are wholly obsolete, but this occurs in the females only. The venter is thickly clothed with pale yellow scales.

Habits of the Adult.

Practically nothing is known of the adult in nature. Although it has been bred from a number of widely separated localities be-

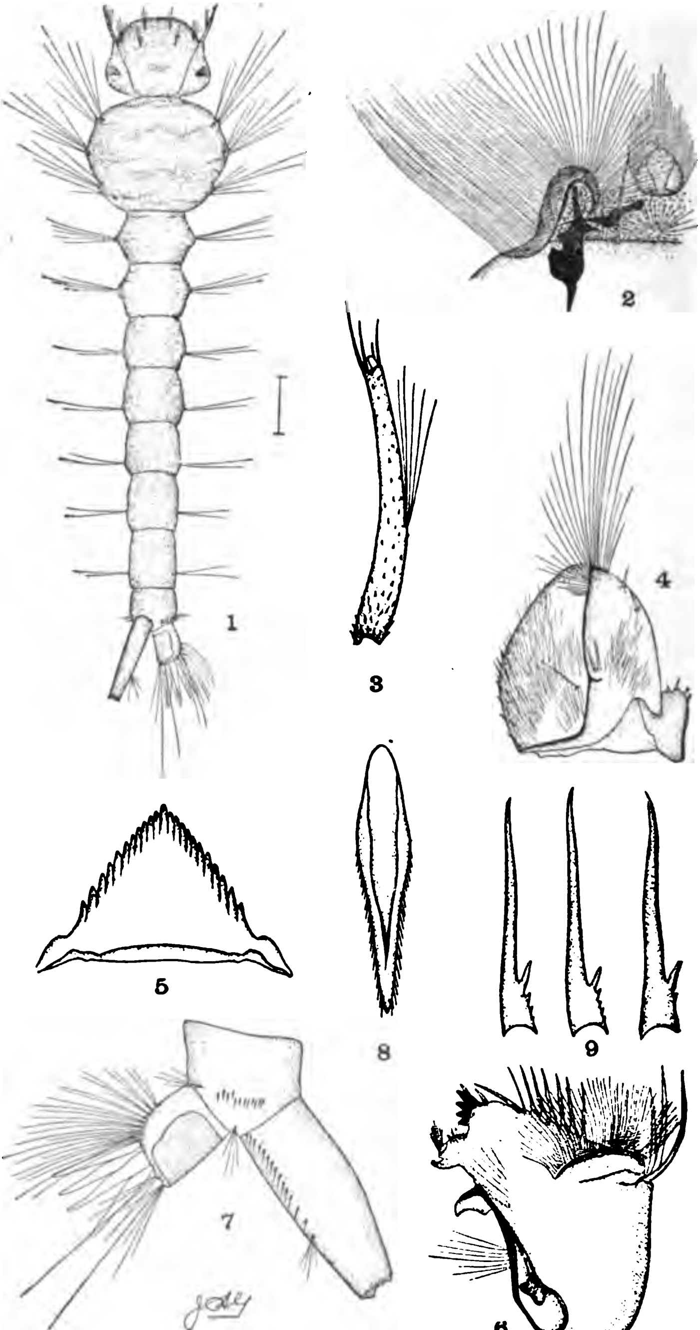

Figure 105.

Aedes fuscus: 1, larva; 2, the mouth brushes; 3, antenna; 4, palpus; 5, mentum; 6, mandible; 7, terminal segments with anal siphon; 8, a single scale of the 8th segment; 9, siphonal spines: all much enlarged. (Original.)

tween the Black River Swamp in the north and Lahaway in the south, yet it has been taken on the wing once only, at Metuchen, by Mr. Grossbeck, May 7th. When this specimen was brought in, with larvæ enough to indicate its rather common occurrence, Mr. Grossbeck was especially directed to seek adults and if possible to ascertain whether they would bite; but no more were taken. It is not probable that it gets very far away from its breeding places and none of the material sent in by Mr. Brakeley, taken indoors or outdoors, ever contained this species. With such a record, which makes it impossible to determine whether or not the insect can or will bite even under the most favorable conditions, it can hardly be considered a pest.

Description of the Larva.

The larva with details of structure is figured on plate figure 105. The full grown wriggler measures 7–8 mm.,=.28–.32 of an inch in length excluding the anal siphon and greatly resembles an ordinary *Culex canadensis* or *sylvestris;* but is much more slender than either. It is light gray to dark slate gray in color, except the head and anal siphon. The head is broader than long, pale yellow or darkly infuscated and has often a brown crescent-shaped mark and several smaller spots in the center of the vertex. Four small hair tufts of four or five hairs each arise from the anterior part of the vertex and two larger tufts are at the base of the antennæ. The antennæ (fig. 105, 3) is moderately long, rather slender, tapering evenly toward the apex and with the tuft well below the middle, composed of but five or six hairs which do not reach the apex; the surface is set with small spines, thickly at the base, sparsely toward the tip, and the apex has three long spines, a short one and a small joint. The rotary mouth brushes (fig. 105, 2) are composed of simple hair, and the mentum (fig. 105, 5) is an almost equilateral triangle with nine to thirteen small teeth on each side of the apex. The maxillary palpus (fig. 105, 4) is normal, the apical tuft moderate, the basal joint small and stout, while the surface is thickly covered with patches of hair and some small spines. The mandible (fig. 105, 6) is normal in form but peculiar by having three curved dorsal spines.

The thorax is circular in outline with the six lateral hair tufts issuing from acute, darkly infuscated tubercles; there is no tuft on the anterior margin.

The abdominal segments are subquadrate on the anterior segments, becoming elongated posteriorly, with lateral hair tufts

of two hairs each; except the first two segments which have four or five hairs to the tuft. The eighth segment has short tufts only and bears the lateral combs. These consist of twelve scales each, arranged in an irregular single row. The scales are elongated, with short, fine, lateral hairs on the apical two thirds (fig. 105, 8). The anal siphon is four times as long as broad, yellow or pale brown in color, tapering slightly on the apical half. The double row of spines has from twelve to sixteen spines in each, the apical two separated from the rest and from each other; the individual spines (fig. 105, 9) slender, each with one large tooth and often one to four very small ones below it. The ninth segment is considerably longer than broad, with the dorsal plate extending lower than the middle; the double dorsal tuft and ventral brush normal, the latter with several small tufts below the barred area. The anal gills are slender, longer than the ninth segment.

Habits of the Early Stages.

There is every reason to believe that this species winters in the egg stage; first, because it has been found very early in the larval stage, in company with species of which it is known that they winter in that way and, second, because the larva has been found in pools dry during the winter and only filled by the spring rains. The earliest dates are from Mr. Brakeley, who collected a miscellaneous lot of larvæ April 7th, from which adults of this species were obtained April 13th. It may be in place here to say that these larvæ are so much like others that are found in the same pools early in spring that unless attention is especially directed to them they readily escape recognition. The next date, April 18th, is also from Lahaway, where the larvæ were taken in company with those of *C. aurifer*. The first pupa formed April 19th, giving adult on the 24th; the second formed on the 20th, giving adult on the 25th; a five day period in each case. The fact that this species is not a larval hibernate was definitely settled when, on April 15th, nearly mature larvæ were found by Mr. Brakeley in a pool that had been completely dry during the winter.

April 24th, Mr. Grossbeck found pupæ from which this species emerged, at Mountain View, and May 2nd, Mr. Brehme found the same stage at Arlington. Larvæ, pupæ and adults were found at Metuchen, May 7th, by Mr. Grossbeck, who took quite a number of the early stages during the two or three succeeding days as well. May 10th, pupæ were taken in the Great Peace Meadows from which adults emerged on the 11th and at the

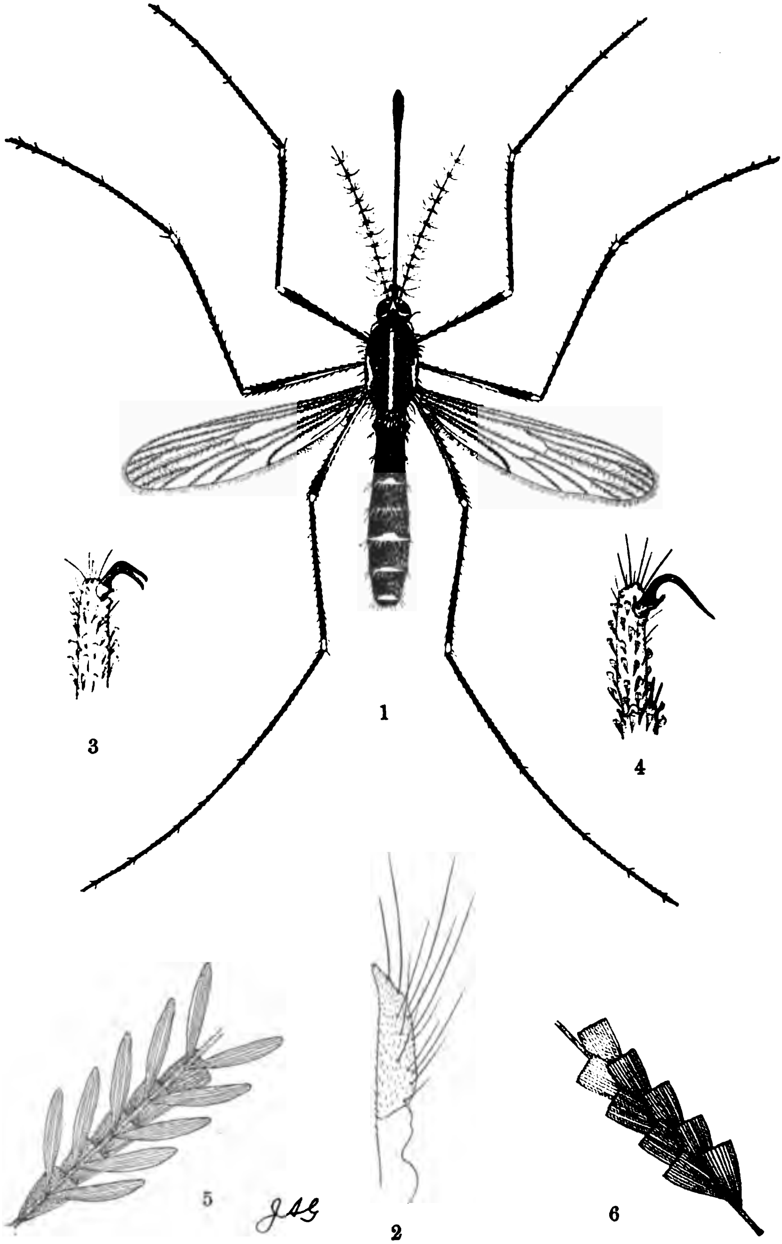

Plate Figure 106.

Uranotænia sapphirina: 1, female adult; 2, her palpus; 3, anterior, and 4, middle claws of male; 5, part of wing vein near outer margin; 6, part of wing near costa, showing scales: all enlarged. (Original.)

same place other pupæ were taken on the 21st, yielding adults on the 22nd. May 26th, larvæ and pupæ were taken by Mr. Dickerson in the Black River Swamp in Morris County and a single example of this species was identified among a lot of *canadensis*.

There are no records of later captures in any stage and it is fair to conclude that there are no late broods.

Mr. Brakeley classes this among the local breeders; that is, a species which he can count upon finding every year in about the same places; but which does not occur in all bodies of water even under similar conditions.

URANOTÆNIA SAPPHIRINA, OSTEN-SACKEN.

The Sapphire-lined Mosquito.

A small dark brown mosquito with the beak and legs unbanded, though there is a large white dot at apices of the femora and tibiæ. The thorax is marked with metallic blue spots and there is a narrow line of the same color down the center of the dorsal surface. The abdomen is narrowly banded at the apex of some of the segments. The wings are unspotted.

Description of the Adult.

This is a very small mosquito, measuring 2.5–3 mm.,=.10–.12 of an inch in length, with a beak almost two-thirds the length of the body. The head is black, with a patch of metallic blue scales in the angle formed by the eyes, and often patches of similar ones on the posterior edge of the eyes, which join the anterior patch; the palpi (fig. 66, 2) are alike in both sexes, short and two jointed, the apical joint with long bristles; the proboscis is brownish, hairy and swollen at the tip. The antennæ in the female are pilose, brown in color, with the large basal joint yellow; in the male they are plumose, dark brown, with paler plumes.

The thorax is brown and has many long, black, curved bristles; a median narrow line of metallic blue scales extends the whole length of the mesonotum, not quite reaching the anterior margin and a short, blue, curved line is slightly anterior of each wing. The patagia are wholly covered with blue scales and appear as lobes from above. The pleura are light brown, with two small patches of blue scales, which are very often connected. The legs

are jet black, appearing dark blue in some lights, whitish on the under side of the femora, and with a large white dot at the apex of the femora and tibiæ, which have a delicate tinge of blue. The claws of the anterior tarsal joint of the male are equal, the outer half sharply curved at right angles to the base, as in figure 106, 3, the mid tarsal joint with but a single long curved claw (fig. 106, 4) set in the joint below the apex, and the posterior the same as those of the anterior, but smaller. The claws of the female are the same as in the male, except that the middle are like the anterior.

Th abdomen is dark brown above, paler beneath, with whitish apical bands on the dorsal surface prolonged forward in the middle on some of the segments, largest on segments three and five in all specimens examined.

Habits of the Adult.

Very little is known of this handsome species, which has been actually captured on one or two occasions only. There is no record of its biting at any time and we have no evidence that it can bite. It occurs, probably, throughout the State, actual records coming from Cape May, Lahaway, Metedeconk Neck, Trenton and Irvington. The dates are always after midsummer.

There is absolutely no chance of mistaking this little species when it can be seen under a sufficient magnification to bring out the sapphire blue scales and lines on the sides and top of the thorax.

How the winter is passed, we do not know; but it would seem as if this were a species that might live over in the adult stage. The eggs, forming a floating mass on the surface of permanent water bodies, are not well adapted to live through in that shape, the larvæ have never been found in winter and their surface habit opposes that suggestion.

Description of the Larva.

The larva is illustrated on figure 107, with details of structure. When full grown it is 5–5.5 mm.,=.20–.22 of an inch in length to the end of the ninth segment and yellowish brown or grayish in color. The head is small, elongated, broadest immediately behind the eyes, excavated a little before the antennæ and rounded in front. It is generally an even dark brown in color, though often irregularly marked with yellow or pale brown. Four stout setæ arise from the vertex in the anterior part, each from a sep-

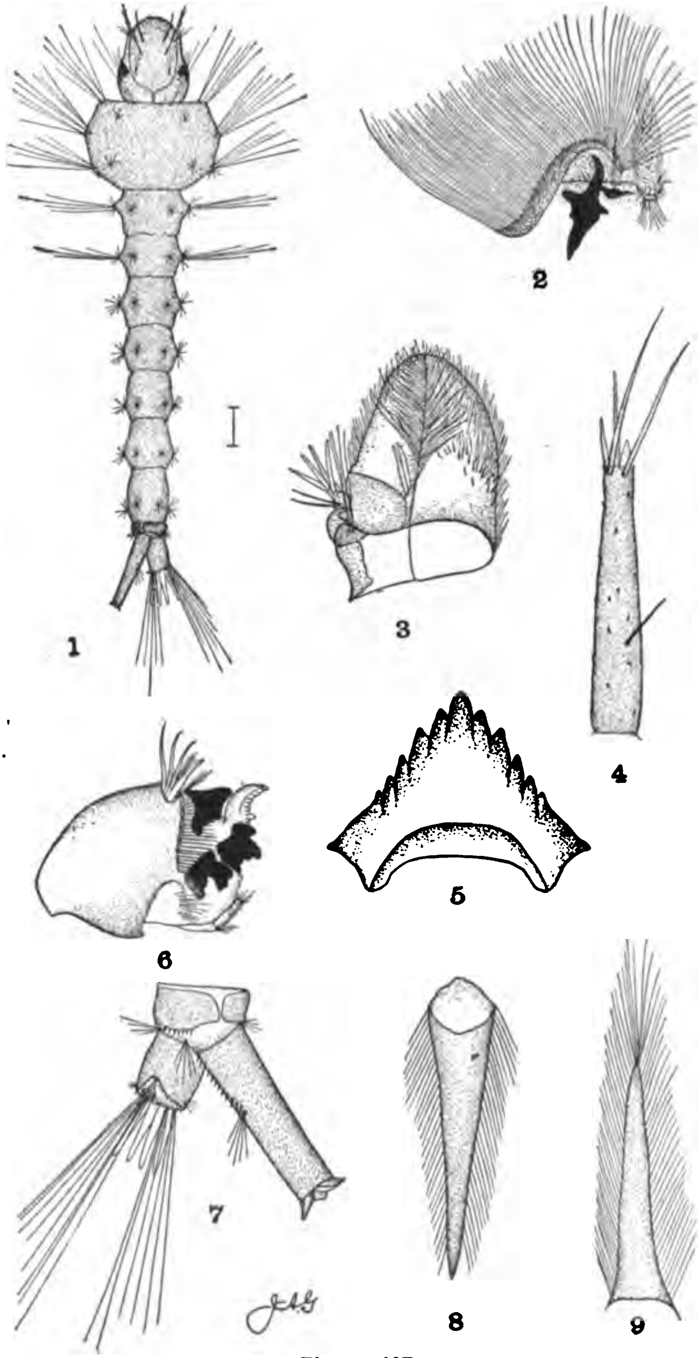

Figure 107.

Uranotænia sapphirina: 1, larva; 2, mouth brush; 3, palpus; 4, antenna; 5, mentum; 6, mandible; 7, terminal segment and siphon; 8, one of the scales; 9, a siphonal spine: all much enlarged. (Original.)

arate pit, the pits so arranged as to form a square; a small tuft of four or five hairs is also at the base of each antenna. The antenna (fig. 107, 4) is uniformly brown, rather short, sparsely set with short spines and terminating with two very long spines, two shorter ones and a small joint; the tuft is represented by a single stout seta situated one-third from the base. The rotary mouth brushes (fig. 107, 2) are small, composed of simple hair. The mentum (fig. 107, 5) is triangular, very chunky, with nine or eleven blunt teeth, the largest at the apex, the smallest toward the base. The mandible (fig. 107, 6) and the maxillary palpus (fig. 107, 3) are also both chunky, the former peculiar by a group of blunt black teeth and four dorsal spines, one of which is finely comb-toothed, while the latter has no apical tuft, but is thickly clothed with short hairs, and the basal joint is small, with four very long, blunt terminal spines.

The thorax is angular and at least one and one-half times as broad as long, each lateral angle giving rise to long hair tufts. Two smaller tufts are on the anterior margin and six stellate hairs, two in the anterior part and four in posterior part are on the dorsal surface.

The abdominal segments are subequal, rather deeply constricted at the sutures. The lateral prominences of the anterior two segments have each about four long hairs, the following segments with only short stellate hairs at the sides. On the dorsal surface each segment has two other stellate hairs, in addition to the lateral ones. The eighth segment has large lateral plates, with a row of six to nine stout spines on the posterior edge, each spine finely fringed with hairs at the sides, as in figure 8. The anal siphon (fig. 107, 7) is three to three and one-half times as long as broad, only a little narrower at the apex than at the base and is slightly concave; the apex with four processes, which are dilated so as to flare at the tip.

The lateral rows of spines are composed of from twelve to fourteen each, the single spine (fig. 107, 9) destitute of basal teeth, but fringed with fine long hairs at the base and apex. The ninth segment is longer than broad, with the anal gills about as long as this segment; the double dorsal tuft and ventral brush composed of long hairs of equal length, the latter very small and confined to the barred area.

Habits of the Early Stages.

The early stages of this species were observed by Mr. Brakeley and myself at Lahaway and by Dr. Dyar, at Bellport, Long Island. The latter published an account in the Journal of the

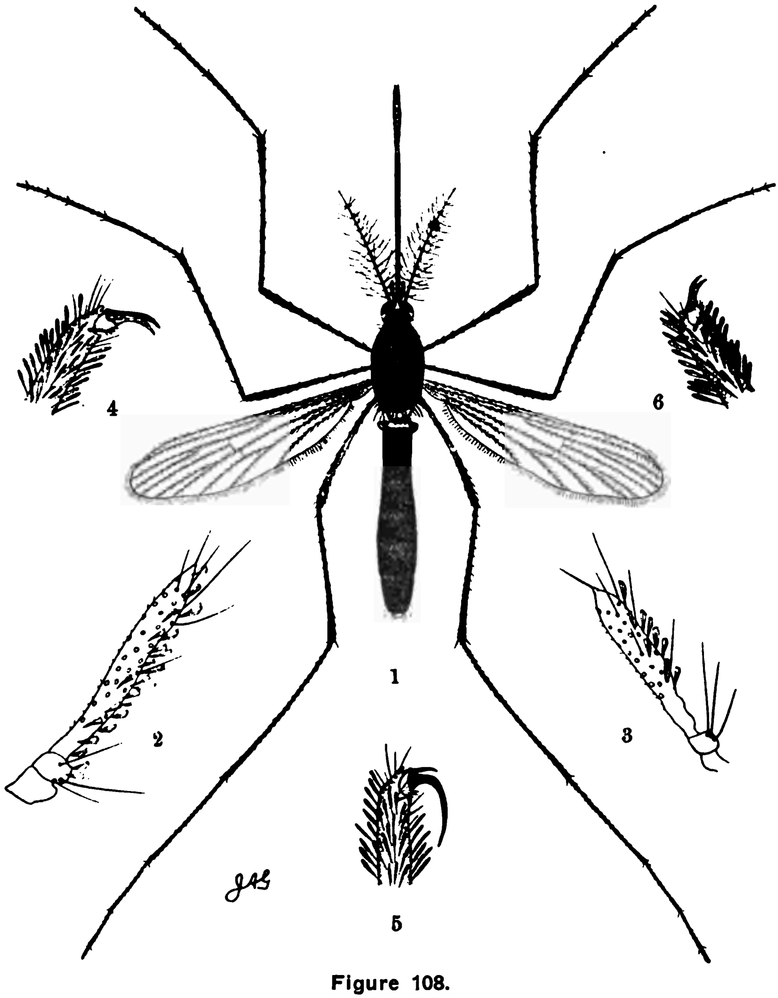

Figure 108.

Wyeomyia smithii: 1, female adult; 2, her palpus; 3, palpus of male; 4, anterior; 5, middle, and 6, posterior claws of male: all much enlarged. (Original.)

New York Entomological Society, which agrees in substance with my observations and which it will be convenient to quote: "The eggs form a boat-shaped mass floating on the surface of the water, much as in *Culex pungens,* but the mass is smaller, containing a less number of eggs and is less regularly elliptical, more angular. It floats less on the surface, the middle eggs being nearly half submerged. The sculpture and color of the individual eggs are also different. The newly--hatched larva at once takes up the usual feeding position. This is essentially as in *Culex,* but the body is held more flatly, more parallel to the surface, yet below the surface film. Consequently, though feeding as *Culex,* the larvæ resemble *Anopheles* at a casual glance and were several times at first mistaken for them. The larvæ are fond of resting below the leaves of the *Lemna,* where they remain with the air tube penetrating the surface and feed, often with a rotary motion of the body on the air tube as an axis. Occasionally they bend up to feed at the surface. They are not timid and often a considerable commotion of the water is necessary to send them to the bottom. The head may be partly rotated on the neck, but the habit is not so completely developed nor so frequent as in *Anopheles,* which regularly feeds with the head inverted. It has an elongate, dark brown head with a contrasting pale body, the hairs of the anterior abdominal segments markedly longer than those of the succeeding ones. Of the local species (at Bellport), it most suggests the species of *Anopheles,* as above noted. The long anterior hairs assist in the deceptive appearance. There seem to be four larval stages, the last three being essentially alike, except for the successively larger size. This is shown best by the head as in Lepidopterous larvæ. The head gradually becomes paler, being black in the young larva and brown in the large ones. The pupa resembles that of *Culex,* but is very small and has unusually long air tubes. The species seem to breed continuously all summer, preferring warm, stagnant pools of some size, containing *Spirogyra.*"

At Lahaway I found the egg boats near the shallow edge of a large fish pond and the larvæ among the vegetation along the shallow edge of a lily pond in late June. Mr. Grossbeck found larvæ in Cadwalader Park, Trenton, August 5th; Mr. Brehme found it at Metedeconk, September 23d, and at Irvington, September 15th. Mr. Brakeley has found single specimens at different periods during the summer. It is what he calls a local breeder, being found in about the same places each year and always in permanent bodies of water.

The resemblance to *Anopheles* with a long breathing tube is so strong that I could scarcely persuade myself when I first saw the larva that it did not belong to that genus.

WYEOMYIA SMITHII, COQ.

The Pitcher Plant Mosquito.

A small black mosquito with the abdomen, legs and proboscis unbanded, and the wings unspotted. The whole under surface, including the sides of the thorax and part of the under side of the legs is yellowish or silvery white, strongly in contrast with the black upper side.

Description of the Adult.

This mosquito is very small, measuring, exclusive of the beak, 3 mm., or .12 of an inch in length. The proboscis is comparatively very long, being two-thirds the length of the body; it is black in color, slender and slightly swollen at the apex. The head and eyes are jet black above; beneath are silvery white scales which extend up the posterior border of the eyes and approach slightly on the dorsal part; there is a very small patch of similar scales on the anterior part of the head in the angle formed by the eyes. Rarely these scales are diffused and form an indistinct border to the posterior margin of the eyes. The palpi are short in both sexes (fig. 108, 2, 3), shortest in the male, and are composed of three segments each, the apical one long, the basal ones small with weak sutures; they are brownish black in color, sparsely set with bristles, one directly on the apex, and the scales do not cover the surface densely. The antennæ are fourteen jointed, precisely the same in both male and female, the penultimate joint slightly longer and the apical one twice as long as the others. They are almost black, pale at the base and set with basal whorls of long bristles which become gradually shorter toward the apex.

The thorax is evenly blackish brown, rather sparsely covered with short concolorous hair and occasionally grayish scales are diffused over the surface or collected into irregular stripes. The pleura are pale brown with several small patches of silvery white scales and one small patch of bright violaceous ones in the anterior angle. The legs are black, with the under side of the femora and tibiæ light yellow, the tarsi black with brassy yellow

reflections. The claws of the anterior tarsal joint in the male (fig. 108, 4) are equal and simple, those of the mid tarsal joint (fig 108, 5) are unequal, the larger very long and curved, the smaller about one-fourth its length, straight and very acute; the posterior claws (fig. 108, 6) are like the anterior, but smaller. The female claws are the same as in the male except that the mid claws are like the anterior ones.

The abdomen is swollen posteriorly, brownish black on the dorsal surface, with metallic bronze reflections. The venter is yellowish, densely covered with silvery white scales which join the brown in a well defined line at the sides; sometimes the white extends very slightly up the base of the segments, but is never visible from above.

Habits of the Adult.

The most characteristic habit of the adult is its inability or disinclination to bite and suck blood—of human beings at least. Mr. Brakeley has been in the bogs and swamps where there must have been hundreds of them and never a one has come to disturb him. He has even seen them about, among the pitcher plants, apparently engaged in ovipositing, and they paid not the slightest attention to him.

Since the spring of 1901 hundreds of specimens have been annually bred in my laboratory and often examples escape. On one solitary occasion a specimen lit upon my hand resting on the back of a chair, and I kept very quiet for several minutes watching it. It moved about a little, touched the surface with its beak several times with a sort of jabbing motion; but made no real attempt to puncture. It tried to assume the resting position but seemed to be annoyed by the hair on the hand and after shifting about for a little flew away to seek more satisfactory quarters. It is the first and only time that a New Jersey mosquito of any kind declined the opportunity to feast upon me!

The resting position, by the bye, is peculiar; the head points downward at an angle to between the front legs and the hind legs are curled over so far as to give the insect the appearance of attempting a somersault and being caught midway in the attempt.

The adults do not make their appearance under natural conditions until the end of May, and issue irregularly until the end of October or even early November.

They are found throughout the southern part of the State wherever the pitcher plant grows; but the larvæ do not seem to inhabit pitcher plants in the Passiac swamps so generally. We

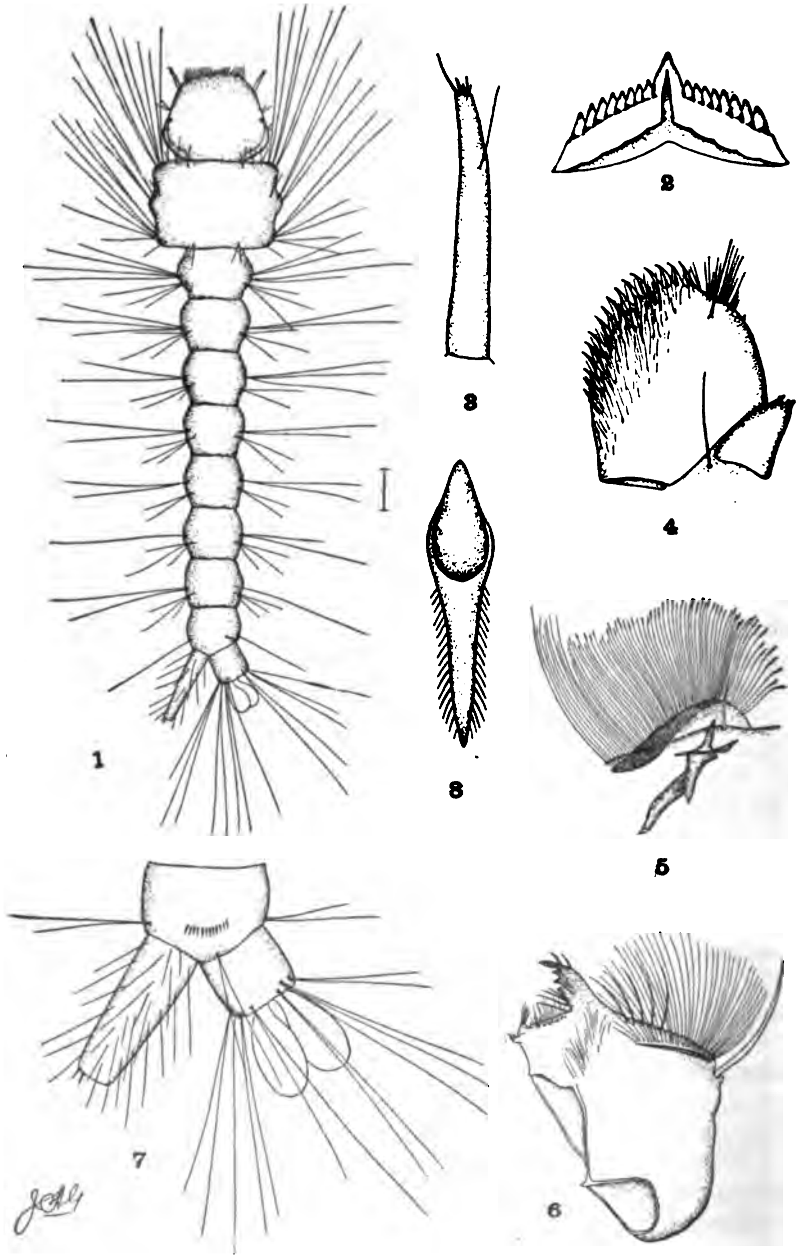

Figure 109.

Wyeomyia smithii: 1, larva; 2, mentum; 3, antenna; 4, palpus; 5, mouth brush; 6, mandible; 7, terminal segments, with siphon: all much enlarged. (Original.)

have found them only in 1904 and then not common. Just why they should not occur there so abundantly I am unable to say, unless these northern swamps are enough colder in summer to prevent free development.

Nothing has been observed as to the length of adult life and nothing is known of their feeding habits. Mr. Brakeley has seen them apparently ovipositing during the day, but never in large numbers. I have never found them on flowers and the inference is that they are, under ordinary conditions, active only at night.

There is little or no difference in appearance between the sexes.

Description of the Larva.

The larva is illustrated on figure 109 with details of structure. When full grown it averages 5–6 mm.,=.20–.24 of an inch in length excluding the anal siphon, though many specimens attain the length of 7 mm. In color they are creamy white with the head slightly darker. The head is rounded, pentagonal and almost as long as broad. The antennæ (fig. 109, 3) are small, uniformly pale brown, the tuft represented by a single hair which issues from the shaft slightly over one-fourth its length from the apex; the apex with several small spines and one longer one. The eyes are very small, round, but often (especially in large larvæ) have a crescent shaped mark immediately before it. The rotary mouth brushes (fig. 109, 5) are bright yellow, the hairs composing them being pectinated at their extreme tips and the mentum (fig. 109, 2) is broadly pentagonal in form, concave at the base, with a large apical tooth and from seven to ten uniform smaller ones on each side; nine being the usual number. The palpus (fig. 109, 4) is longer than wide with a rudimentary apical tuft, a stout basal joint, and a row of acutely pointed processes on one side. The mandible (fig. 109, 6) is shaped as in *Culex,* but has only a single curved dorsal spine and is excavated between this spine and the apex. The thorax is quadrate, broader than long, has sinuous lateral margins, each with three groups of long hair tufts, and there are several short ones on the anterior and posterior margins.

The abdomen is slender, the segments similar, with long lateral hair tufts of four or five hairs to each tuft in the anterior segments, and two or three in the posterior ones. A number of shorter tufts below and above these long ones are on each of the segments. The lateral combs of the eighth segment consist, each, of eleven to fifteen scales arranged in a single row,

the individual scale (fig. 109, 8) elongated and fringed with short hairs at the sides. The anal siphon is four to four and one-half times as long as broad at the base and tapers evenly toward the apex. It is creamy white in color, with the apex brownish; the lateral rows of spines are entirely wanting but the surface is set with numerous long hairs which are scattered unevenly (fig. 109, 7). The ninth segment is almost square with tufts of long hair on the apical margin and two small processes representing the gills.

Habits of the Early Stages.

My first acquaintance with the insect began in late November, 1900, when Mr. J. Turner Brakeley called my attention to the fact that, in the pitcher plants in the swamps surrounding his cranberry bogs at Lahaway, there were what he thought mosquito larvæ. The matter did not interest me very strongly at the time. I verified the fact that they were mosquito larvæ and, because that species was common about there, I assumed that it was *pungens* (*pipiens*). Dr. Howard's pamphlet on mosquitoes had been not long since published, and the larvæ in the leaves of the plant fitted to his pictures and description sufficiently well. As *Culex pipiens* breeds everywhere, it did not strike me as especially odd that the larvæ should be in the leaf pitchers, and I assumed that they were, probably, present in the bog holes and ditches as well.

In reply to the question, what will become of these larvæ, I informed Mr. Brakeley that *Culex pipiens* hibernated as an adult; that the larvæ are dependent upon atmospheric air and that these specimens would undoubtedly die when the winter fairly set in. Mr. Brakeley looked unconvinced; but said nothing at the time.

Though the weather was yet mild, mosquitoes were no longer obtrusive. There were occasional specimens to be sure, but they seemed to be left-overs, not yet in hibernating condition. The species, unfortunately, was not determined; I was not yet, at that time, a mosquito crank. The interesting point was that in every leaf examined there were wrigglers, varying in size from an eighth to a quarter inch in length. There was always a mass of insect fragments at the bottom, say from one-half to an inch in depth, and in composition this varied from a dense black ooze at the lowest point to entire or only partly decayed specimens at the top of the mass.

The matter dropped here until January, 1901, when Mr. Brakeley, who believes that nature wastes nothing, not even

mosquito wrigglers, made an investigation of swamp conditions during a bitter cold spell. He cut out a few of the pitcher plant leaves, stripped them from the core of solid ice that they contained and, looking through it, saw wrigglers imbedded in all parts, in all sorts of shapes; but mostly in a half coil. The temperature had been down to two degrees below zero as registered by a standard minimum thermometer, and radiation probably lowered this even more.

A number of leaves were gathered, the cores of ice with all they contained were removed, and the lumps were placed together in a jar in a moderately warm room. The ice melted slowly, and, as the larvæ were gradually freed, they dropped to the bottom where, for a time they rested; apparently lifeless. But as the amount of ice decreased, feeble motions here and there indicated a revival and, long before the lumps were completely melted, those first released were moving about actively. This, be it noted, was in water not much above the freezing point and, when the ice had all melted and the debris had settled, the larvæ became busily engaged in feeding.

The specimens were sent to me as a curiosity, January 22d, and arrived in very good condition. A few had succumbed to the dangers of the journey, but, altogether, there was a good lot of lively wrigglers. The bottle was nearly full of water, it had had a five mile wagon drive over a rough road, had been transhipped no less than four times before it reached New Brunswick, and then was thrown into a delivery wagon and jolted through the city streets before it actually reached me. Under these circumstances any regular breathing of the kind usually described was utterly out of the question and the drownings should have been numerous; but really only a small number died.

At short intervals other jars were received, all out of melted ice taken from pitcher plants, until I had several hundred active wrigglers in eight different jars. Some of the leaf chunks had only ten or a dozen larvæ, others ran as high as thirty or more. The jars were all placed on a counter shelf near a steam radiator, and it was expected that in a few days there would be pupæ and adults. But the days passed into weeks and the weeks into months without change other than a very gradual increase in size. The larvæ were just as active as could be expected and fed continuously, but they showed no disposition to change their condition.

As the fragments settled the water became clear and the larvæ congregated over the sediment, feeding head down and frequently rooting into it. It was rare that an individual was observed at the surface with the spiracle in breathing position.

I watched patiently for fifteen minutes at a time, without noting a single individual rising to the top and Mr. Dickerson watched almost continuously one day for two hours and declares that during that time only a small percentage of the entire number rose to the surface.

Occasionally a number of specimens would be at the surface, feeding, head up, so that the mouth brushes skimmed the surface, and these were watched on occasions for twenty minutes, without noting any attempt to assume the breathing position. In fact, during the two months that these larvæ were under daily observation, the rising to the surface to breathe was the rare exception rather than the rule. Usually they were feeding, head down, over the bottom sediment, or head up along the sides of the jar and at the top. The mouth brushes serve also as organs of locomotion and the larvæ were able to make their way from one point to another, without moving any other part of the body. They often allowed themselves to sink slowly to the bottom without any motion whatever, and sometimes to sink more rapidly curled themselves up into a ring. Occasionally a specimen got hold of a bubble of gas formed at the bottom and allowed itself to be floated to the surface. It was interesting to watch the little fellows; but as week after week passed it became just a little tedious; therefore, to hasten matters, I placed, March 1st, the two jars first received on a water bath, which kept the temperature as nearly uniform as the varying pressure of the gas allowed—say between eighty degrees and ninety degrees Fahr.

A difference in growth was observable after a few days and on March 18th the first pupa was noticed, from which an adult was produced on the 21st, a period of three days. Three other pupæ were obtained within a week and these changed to adults in about the same time.

March 24th, I made an experiment which resulted fatally. It occurred to me that the slow growth might be due to lack of food and as Mr. Brakeley wrote that his larvæ attacked and devoured a small gnat I determined to add food to the water. Accordingly I placed a small lump of beef in each of five experiment jars. Next day at a casual glance I noted nothing unusual, but March 26th, at 8 a. m., I found the insects at the top, tube out and evidently in distress. I fished out all the meat particles at once, but the mischief had been done, and most of the larvæ died. Evidently this species does not thrive in foul water; a fact which Mr. Brakeley determined also from his field collections.

As the season progressed, Mr. Brakeley kept sending in larvæ and these matured in such numbers that I was able to supply material in sufficient quantity to enable Mr. Coquillett to deter-

mine that instead of *Culex pipiens* we had a new species to deal with; one which will have to descend to posterity as a member of the Smith family, unless perchance it proves to have been previously described.

Mr. Brakeley kept a duplicate series of specimens under observation at Lahaway, and his first pupa, from larvæ thawed out of ice February 17th, was obtained April 16th, and became adult on the 26th. This gives a period of fifty-eight days in active larval life, at an ordinary indoor temperature, or sixty-eight days if the pupal period is counted. Other pupæ and adults developed and the pupal period ranged between ten and twelve days. A small lot of specimens gathered April 7th began pupating May 1st, and these had an average pupal period of eight days.

Altogether Mr. Brakeley sent me, prior to May 1st, some fifteen to twenty lots of larvæ, numbering many hundreds of specimens. All these were kept in the original pitcher leaf water and this never became foul. It required the contents of from forty to seventy-five pitchers to make a full pint of liquid, and the larvæ numbered from two to twenty or more in each leaf. Culture after culture was closed out during the summer; but though the conditions for all the larvæ in a single jar were absolutely the same, the rate of development varied in each individual. One quart jar, containing nearly 200 larvæ, received in early March, developed adults throughout the summer, and this was not closed out until September 13, 1901, six months after its receipt, when there were yet a few larvæ, two or three pupæ and one or two adults! These larvæ had been surely hatched in November, 1900, and had remained in that condition for certainly ten months, including the entire summer.

May 31, June 1 and 2, were spent at Lahaway with Mr. Brakeley, and during those days the swamps for some distance around were visited and dozens of pitcher plants closely examined.

In the areas flooded during the winter by cranberry bog operations, no larvæ were found; but as soon as the flood line was passed, larvæ were taken; generally half a dozen or more to a leaf. But none occurred except in the leaves. This point was tested very thoroughly throughout the season and it is absolutely certain that this little species does not occur anywhere outside of the receptacles formed by *Sarraccnia,* except by accident. In the colder, shaded parts of the swamp, where springs occurred, larvæ only were found. In the warmer areas pupæ were common and, in some places, where water and moss surrounding the plant were actually tepid, the insects had already emerged and nothing but empty pupa shells could be found. It seems to be entirely a matter of temperature, and in some of the coldest

places, no transformations would be likely to occur much before late June. It is certain that most hibernating larvæ live from early November to late May or early June, a period of fully six months. No adults could be found and certainly none made any attempt to bite. Nor could egg masses or young larvæ be discovered at this time. New leaves were developing and few yet contained any water. Such of these as were examined contained no insect life and only here and there one had trapped insects; none had begun to digest or assimilate the animal food.

An open swamp at the head of a cranberry bog had most of the leaves with pupal shells only, but though there must have been hundreds of adults about, not one could be found flying, nor could we stir them up. In a deep, cold, huckleberry swamp, only larvæ were found. It was fair to conclude from the three days' tramp that no summer brood of larvæ had yet begun, and it seemed strongly indicated that the insects would not bite, even if given the opportunity. In confirmation it may be said that late in the summer Mr. Brakeley saw specimens flying, and though there must have been thousands of others round about, none made any effort to disturb him.

July 3d, the leaves contained half and full-grown larvæ, but neither pupæ nor very small larvæ. July 13th, old and new leaves contained very small larvæ—evidently of recent date, while the old leaves had also grown larvæ and pupæ. There was, therefore, a new series of larvæ and probably the first summer brood. July 23d, the older leaves had very few larvæ, but almost as many very small as large ones. The new leaves had all stages, from very small larvæ to pupæ. The indications were, therefore, that the first summer brood was coming to maturity, developing in from fifteen to twenty days, while there were yet adult individuals from the winter larva that were ovipositing. From the small number of young larvæ in individual leaves, the indications were that eggs were laid either singly or in small groups.

The next sending did not come until August 21st, and then there was everything from the most minute larva to pupæ just ready to transform. So small were some of the larvæ that I hunted for eggs or egg shells, but failed to recognize any. It is probable that the youngest larvæ represented a third brood, but breeding was practically continuous, all stages being found at any time after the middle of July.

September 1st, the same conditions existed and there was a large number of larvæ so small that it seemed as if at least egg shells must yet remain, but none were found. Fortunately Mr.

Brakeley returned to Lahaway early in this month and on the 13th—lucky day—he found the eggs floating on the surface of the water in the pitcher plants.

September 14th, I had an opportunity to spend a couple of hours in a swamp in the pines near Hanover Station, Burlington County, and found the pitcher plants there full of the *Wyeomyia* in all stages from babes to pupæ. Collected the entire contents of the pitchers in alcohol, and found afterward that eggs were present in some numbers. But meanwhile Mr. Brakeley had positively identified them, and had even bred a lot of larvæ, making the relation absolutely certain. He collected from time to time, until October 20th, and found anywhere from five or six to thirty or more eggs in a single leaf. Oviposition was continuous, but on only two occasions were adults seen apparently engaged in the process. It is probable that the egg-laying is done mostly at night.

After the eggs had once been identified there was no difficulty in finding them, but it was noted that in the older leaves where larvæ were now most abundant, they were not so plentiful as they should be to account for the large winter supply. So attention was directed to the younger leaves, even where there was as yet no water in them. Here, it was discovered, was the favorite place for ovipositing, with this species. Eggs were laid in leaves as yet perfectly dry, at the bottom and at the sides, singly or in little groups, whether by one or more than one female was not ascertained. Of the old leaves many become imperfect in late fall and any puncture or decay allowing the water to escape would, of course, mean the death of the larvæ. So the new leaves are selected and in them many more eggs were found than in the others. In one case Mr. Brakeley counted up to seventy-five, then lumped the remainder and called it one hundred. It is scarcely probable that any one female of this species is capable of producing one hundred eggs of the comparatively large size of those in question; so two at least, and possibly more females may oviposit in a suitable leaf.

Observations were continued until frost, which came unusually early in 1901. Up to November eggs were found, and early in that month a few pupæ. So breeding is continued just as long as there is a chance to keep it up.

The eggs are chestnut brown in color, somewhat chunky, bean-shaped, the ends somewhat pointed, the inner margin nearly straight. There is no evident sculpture, yet when first mounted and examined under the miscroscope, there seems to be a some-

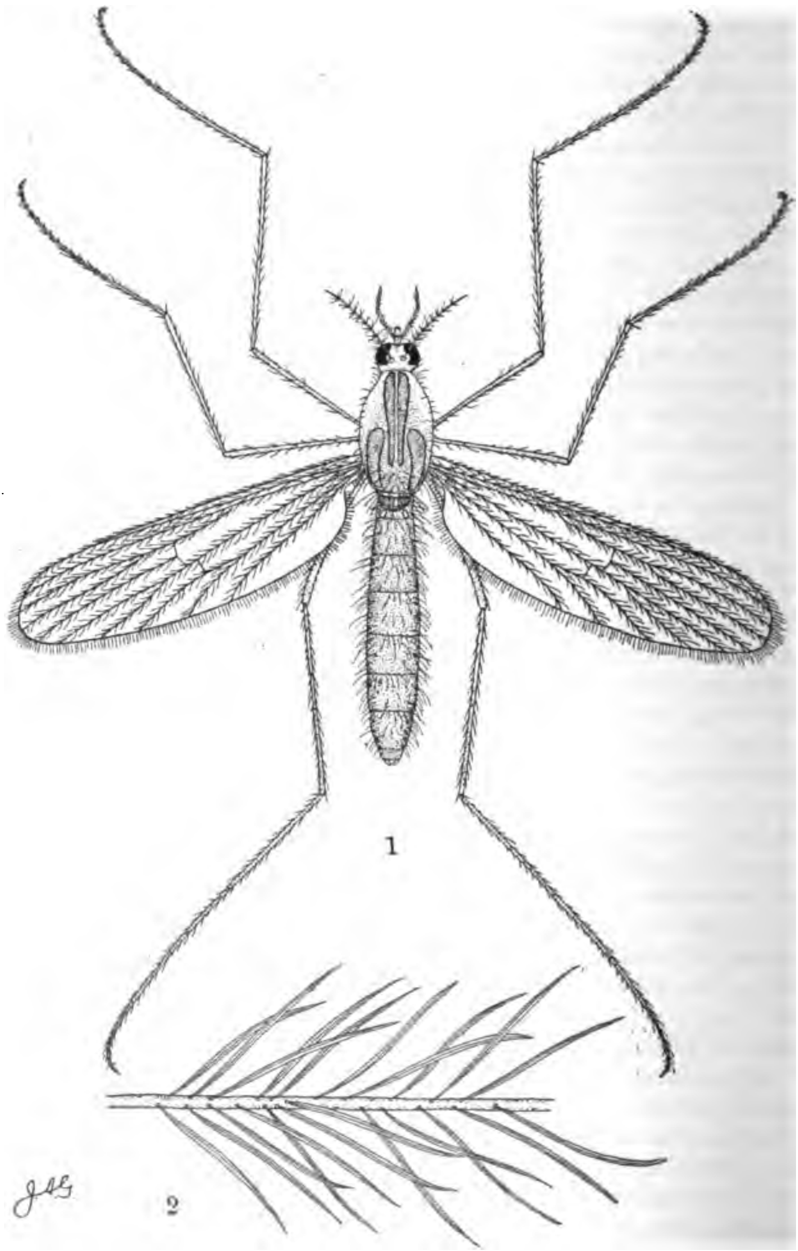

Figure 110.

Sayomyia albipes: 1, adult female; 2, part of wing vein to show scales: much enlarged. (Original.)

what irregular tessellated reticulation that disappears later, when the shell becomes more transparent.

In the previous notes it was brought out that this larva does not need to come to the surface for air as much as recorded for *Culex*. Dr. Howard informed me that a lot of larvæ that I sent him later, lived for nearly two weeks under a film of oil which covered the surface of their breeding jar.

One of my students demonstrated in the laboratory a very complete tracheal system in the anal processes of the larva, so we have really a gill structure, by means of which the insect gets its supply of oxygen directly from the water.

Briefly stated, the life history is as follows: The insect winters in the larval stage, freezing and thawing as often as need be during that season. It pupates late in May and becomes adult a week or ten days later. Eggs are laid in the leaves singly or in small groups fastened to the sides or floating on the surface. The summer broods mature in about a month, and there are probably three if not four series, but the broods overlap so much that the breeding is practically continuous. Late in the season the adults select the new leaves for oviposition even if they are yet dry.

Mr. D. W. Coquillett tells me that he has the species from Florida, where it breeds in the leaves of an orchidaceous plant growing on trees.

SAYOMYIA ALBIPES, JOHANN.

The White-legged Corethra.

A medium sized yellowish mosquito, with the beak short, not fitted for biting. The dorsal surface of the thorax with three longitudinal, buff colored stripes, the median not reaching the posterior margin, the lateral two not reaching the anterior margin. The legs and abdomen yellowish, the latter sometimes with pale brown shadings.

Description of the Adult.

This mosquito is illustrated on plate figure 110 and measures from 4.5–5.2 mm.,= .18–.22 of an inch in length. The head is pale yellow, with the exception of the black eyes. The proboscis is about two and one-half times as long as broad, brown in color, from above covered on the basal half by the labrum,

which is also brown, with long concolorous hair; the palpi five-jointed, alike, of the same length in both sexes, over twice the length of the proboscis, brown, hairy, the longest hairs basally, the terminal joint long and slender, the basal very short, while the intermediate ones are of moderate length. The antennæ in the female are pale yellow, faintly infuscated distally, rather short, the basal joint globular, the succeeding ones swollen at the base, the two apical longest; a whorl of long hairs at the base of each joint and some very short ones scattered between. The male antennæ are banded, yellow and brown, the plumes very long and dense, and of a pale grayish yellow color.

The dorsum of the thorax is creamy white anteriorly, pale yellowish brown posteriorly, with three longitudinal buff colored stripes, narrowly margined with brown; the median divided longitudinally by a yellow line and terminated about one-third the length of the thorax from the posterior margin; the lateral lines begin at the posterior margin and extend forward to a little over one-half the length of the thorax; the pleura are creamy white or pale yellow, with small black speckles sparsely scattered over the surface. The legs are rather short, clothed with fine hair and pale yellow, except the two last joints of the tarsi, which are grayish brown. The claws are equal and simple on all feet of both male and female and are rather short and stout. The wing veins are covered with long, hair-like scales.

The abdomen is pale buff colored above, sometimes brownish, thickly covered with long concolorous hair, and with small black speckles sparsely scattered at the sides and also on the dorsum of the posterior segments; beneath it is pale yellowish.

Habits of the Adult.

Very little is known of the habits of this little fly, which, though it is a true mosquito in essential structures, does not have the mouth parts developed for biting. It has not been taken in the ordinary collecting and is not, of course, to be classed as a pestiferous form. It has been bred from early May to October, mostly from the northern part of the State, but it also occurs at Delair in Camden County and perhaps yet further south.

Description of the Larva.

The larva, with the head and anal segment greatly enlarged, is illustrated on plate figure 111, figures 1, 2 and 3. The full grown larva measures 12–14 mm.,=.48–.56 of an inch in length; in life

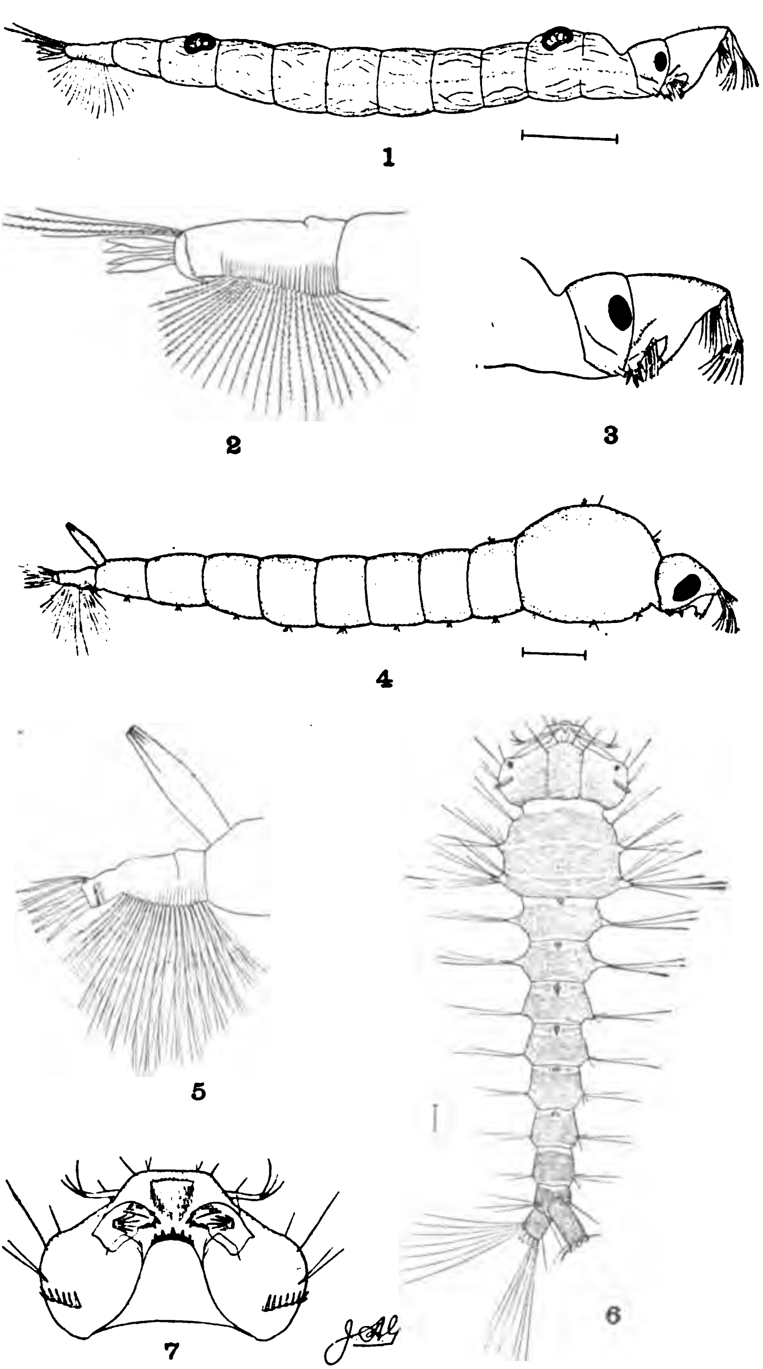

Figure 111.

1, *Sayomyia albipes*, larva; 2, its anal segment; 3, the head; 4, *Corethra cinctipes*, larva; 5, its anal segments and siphon; 6, *Corethrella brakelyi*, larva; 7, its head from beneath: all enlarged. (Original.)

it is almost colorless, except the eyes and four air sacs, which are black, but when put in alcohol it turns to creamy white. The head is sub-conical in shape, the antennæ pendant at the front, with four very long spines at the apex of each. The thorax is broader than the abdomen and bears on its dorsal surface two black air sacs, arranged side by side. The abdominal segments are almost of equal length, tapering posteriorly, and with the seventh segment bearing a second pair of air sacs; the anal segment has on its ventral surface a fan-like arrangement of long feathered hairs issuing from a serrated ridge, and near the end of the segment is a weakly chitinized, transverse plate with small teeth directly anteriorly. The four trachael gills are of moderate length, dilated centrally and four long hairs, two of which are feathered, are directly above the gills.

Habits of the Early Stages.

Mr. Grossbeck believes that this insect winters in the larval stage, but we have no positive evidence on this point. He also believes that the transparent texture is protective and shields the larva from its natural enemies. As a basis for this belief he cites the occurrence of hundreds of these larvæ near Paterson, N. J., October 3, in a pool in which predatory aquatic insects were abundant and in which no other mosquito larvæ occurred. The pool is normally a large piece of water, but had been reduced by drought to a diameter of about eight feet and a depth of one foot. In this all the inhabitants were now concentrated and *Sayomyia* appeared to remain undisturbed. Normally *Culex pipiens, C. territans* and the species of *Anopheles* breed in the shallow edges of the small pond when it is full; but these larvæ had all disappeared, probably eaten by the water tigers, which were plentiful. In life the larva readily escapes detection in even clean water. In alcohol it becomes opaque and of a dull white color. The larvæ are predatory, but not very rapacious, a few *Culex* larvæ lasting a long time in a well stocked jar.

Specimens were found full grown at Arlington, May 2d, in a pool with *Culex canadensis* and *Aedes fuscus* and adults were obtained May 7th. July 14th, Mr. Seal sent in specimens from Delair and these yielded adults July 22d and 23d. The species is apparently common at times from Mr. Seal's report. July 20th, a single specimen occurred with small *Anopheles* and *Culex territans* near Paterson. There were also two small *Psorophora* which were overlooked, and four days later, returning from field work, only the *Psorophora* remained; fifty-three *Anopheles* and

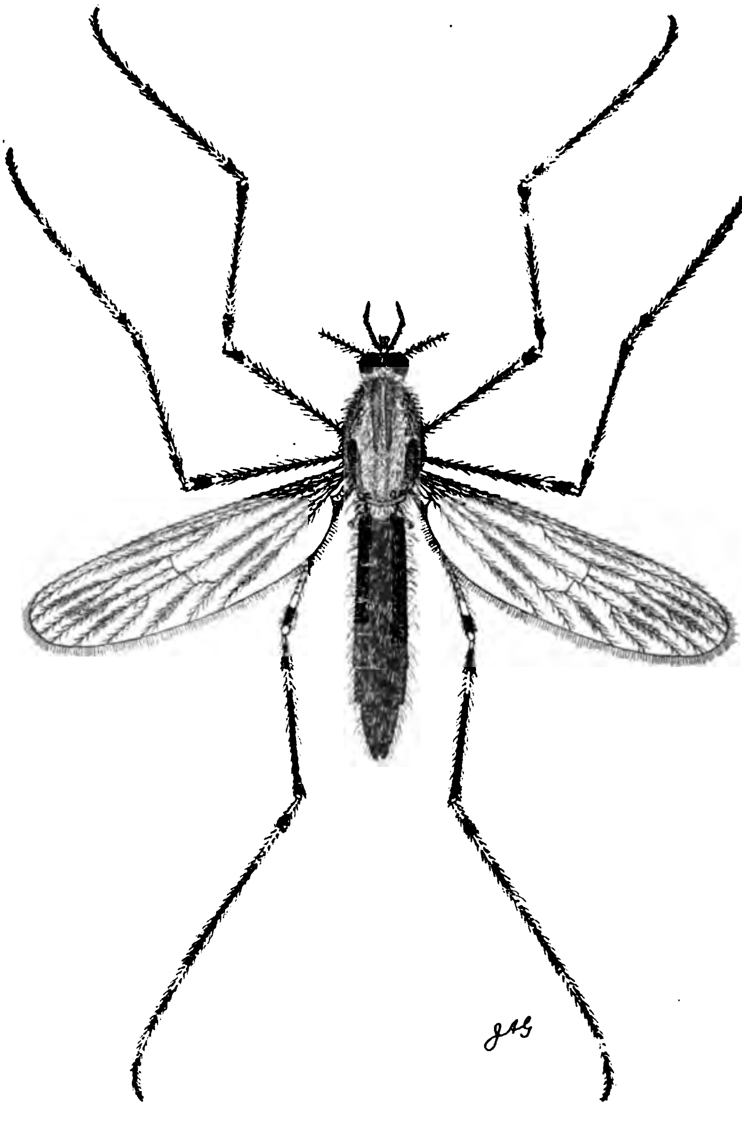

Figure 112.

Corethra cinctipes, female adult: enlarged. (Original.)

almost as many *Culex* larvæ had disappeared. August 16th, two larvæ and two pupæ were found near Newark in company with full grown larvæ and pupæ of *Culex sylvestris* and *C. pipiens;* there was no other food and the larvæ lingered until September 23d, or more than a month, before they died. September 11th, full grown larvæ and pupæ were found in numbers in a woodland pool in the Great Piece meadows, in company with *Anopheles, Conchyliastes musicus, Culex serratus, dupreei* and *territans.* September 16th a few examples were found in a swamp area near Paterson in company with *Culex pipiens* and the last record is that for October 3d already referred to, when only this species escaped from a concentrated pond population of predatory species. The species has never been taken in large ponds containing fish, nor on the other hand, in temporary rain pools or in foul water.

The pupa is as interesting as the larva, almost equally transparent and rests suspended in the water two or three inches from the surface. It has the usual breathing tubes, but does not seem to depend upon them for its supply of oxygen. When it approaches maturity the pupa becomes more opaque, rises to the surface of the water and remains there until the adult appears.

The larva has nothing of the appearance of the other mosquito wrigglers; but the pupa is not unlike those of the more normal species.

CORETHRA CINCTIPES, COQ.

The Ring-legged Corethra.

A medium sized, very robust, dark brown mosquito. The beak is short, the thorax marked with four stripes. The abdomen is uniformly blackish brown in the female, banded with yellowish at the base of the segments in the male. The apices of the femora and bases of the tibiæ are broadly banded with yellow, with a black ring in the middle, and the tarsi are banded with yellow at the base of the joints. The wings are mottled with black and yellow scales.

Description of the Adult.

This mosquito which is figured on plate 112 is of medium size, very robust in appearance and measures 5–6 mm.,=.20–.24 of an inch in length. The head is brown, densely covered with long yellowish hair; the proboscis about two and one-half times as long as broad and brown in color; the palpi alike in both

sexes, shaped as in *S. albipes,* and also brown in color. The antenna in the female is short, the basal joint globular and brownish yellow, the succeeding joints dark brown, paler and swollen at the base, with a whorl of long hairs to each and short hairs scattered between. The male antenna is banded brown and yellow, with silky, pale brown plumes, with yellow reflections.

The thorax is brown with yellow hairs scattered unevenly, and with four dark brown, longitudinal, nude stripes, the two median ones close together, extending from the anterior margin backward beyond the middle, the lateral ones extending from the posterior margin forward to the middle. The pleura are brown with a few dirty white scales. The legs are brownish black; the femora yellow beneath and a broad yellow band at the apex, with a black ring medially but nearer the apex; the tibiæ with a

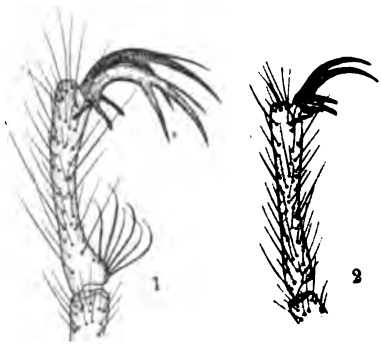

Figure 113.

Corethra cinctipes: 1, posterior claws of male; 2, anterior claws of female: enlarged. (Original.)

small yellow spot at the extreme apex and a broad yellow band at the base, with a black median ring nearer the base. The first joint of each tarsus is very short, the second very long, the succeeding ones normal; all except the apical one banded with yellow at the base, very broadly on the posterior tarsi. The claws of the male anterior and mid tarsal joint are very large, equal in size, and each with a long, slender, median tooth and a blunt basal one, serrated on the inner margin of the basal half. The posterior claws are precisely the same in size and shape, but with an extra thin branch on the outer curve of each claw (fig. 113, 1). The female claws (fig. 113, 2) are alike on all feet, equal, slender, and with a basal tooth, serrated on the inner margin of the basal half as in the male. The wings are grayish hyaline, the veins clothed with black and yellow hair-like scales,

the yellow ones chiefly on the apical and basal portions of the veins, and at the forks, but more or less mixed with the black ones, and it is difficult to determine where one leaves off and where the other begins; as a whole the wings have a mottled appearance.

The abdomen of the female is uniformly blackish brown, with yellowish hairs scattered over the surface; but in the male it has yellowish ill-defined bands at the base of the segments, rather broad on the anterior, narrower or entirely lost on the apical rings.

Habits of the Adult.

Specimens resembling and probably identical with this species have been taken in general collections made by me at Lahaway in years past; none were saved, however and none were collected during this investigation. The insect is really rather a handsome one and, as it does not bite, need not be considered at length. All the adults in our collections were bred.

Description of the Larva.

The larva with the anal siphon greatly enlarged is figured on page figure 111, 4 and 5. When full grown it averages 8 mm., =.32 of an inch in length and is of a pale, partly translucent, reddish brown color with the head and anal siphon more strongly chitinized than in *S. albipes*. The head is dirty brown, comparatively much smaller than the thorax, and when viewed from above is broadest at the eyes, narrowed anteriorly and with two lateral projections in front, from which depend the antennæ The antennæ are rather short, with four long spines of equal length at the apex, curved inwardly. The thorax is rounded, very large and thick, with the first pair of air sacs very faintly visible beneath the integument; small hair tufts are on the lateral margins and a few others on the dorsal surface. The abdominal segments are sub-equal in length, but narrowing posteriorly, each with short lateral hair tufts and the air sacs of the seventh segment are, like those on the thorax, barely discernable. At the posterior margin of the eighth segment is situated the slender anal siphon, which is about four and one-half times as long as its greatest width, slightly dilated centrally and tapered apically. The anal segment is somewhat like *S. albipes,* with a ventral fan of branched hairs issuing from a serrated ridge, and two small tufts of long simple hair above the tracheal

gills. A transverse plate with small teeth directed anteriorly is also on each side, and the tracheal gills are about half the length of the anal segment.

Habits of the Early Stages.

The first record of this larva was March 28th, 1903, when Mr. Brakeley found two examples in the reservoir at Lahaway, with *Culex melanurus* and *C. canadensis*. He noted at that time that they are neither bottom nor top feeders but remain horizontally suspended in the water. From their actions he suspected them of being predatory. Close collecting during the balance of March and early April gave a very few more examples and on April 26th he actually saw a specimen make a dart for a *Culex* larva one-third grown and catch it by the tail. It shook the *Culex* as a dog does a rat and then the wriggler seemed to disappear into the *Corethra* alive. In a few minutes everything was gone except the head and the alimentary canal of the carnivore could be seen filling up through the transparent body wall. On other occasions it was positively determined that they fed on small *Culex* larvæ. Pupation began April 30th and May 1st and the first and only adult of this lot was obtained May 6th. Observation also determined the fact that a full meal made at 2 p. m., on one day was completely digested at 7 a. m. the day following; no trace of the food remaining visible in the alimentary canal.

May 3rd, 1903, a small larva of this species was collected by Mr. Van Duersen at Dayton in company with *canadensis*. May 24th, Mr. Grossbeck collected eighteen examples at Livingston Park and left them without food for twenty hours. At the end of that time one was gone, another was half eaten and some of the others began to die. The last collection for the season was at Lake Hopatcong, July 22nd, a single full grown larva being taken by Mr. Grossbeck.

In the latter part of April, 1904, Mr. Brakeley collected on the water covered bogs full grown larvæ and pupæ of this species in some numbers and on the 29th adults began to emerge. Additional collections made during the early days of May brought quite a number of other specimens and all stages except the egg were well represented. The pupa, like that of *Sayomyia,* is suspended in the water and readily recognizable by the broad anal gills having a distinct dark stripe through the center.

It is not definitely known how the insects hibernate. The water in which most of them were found in early spring at

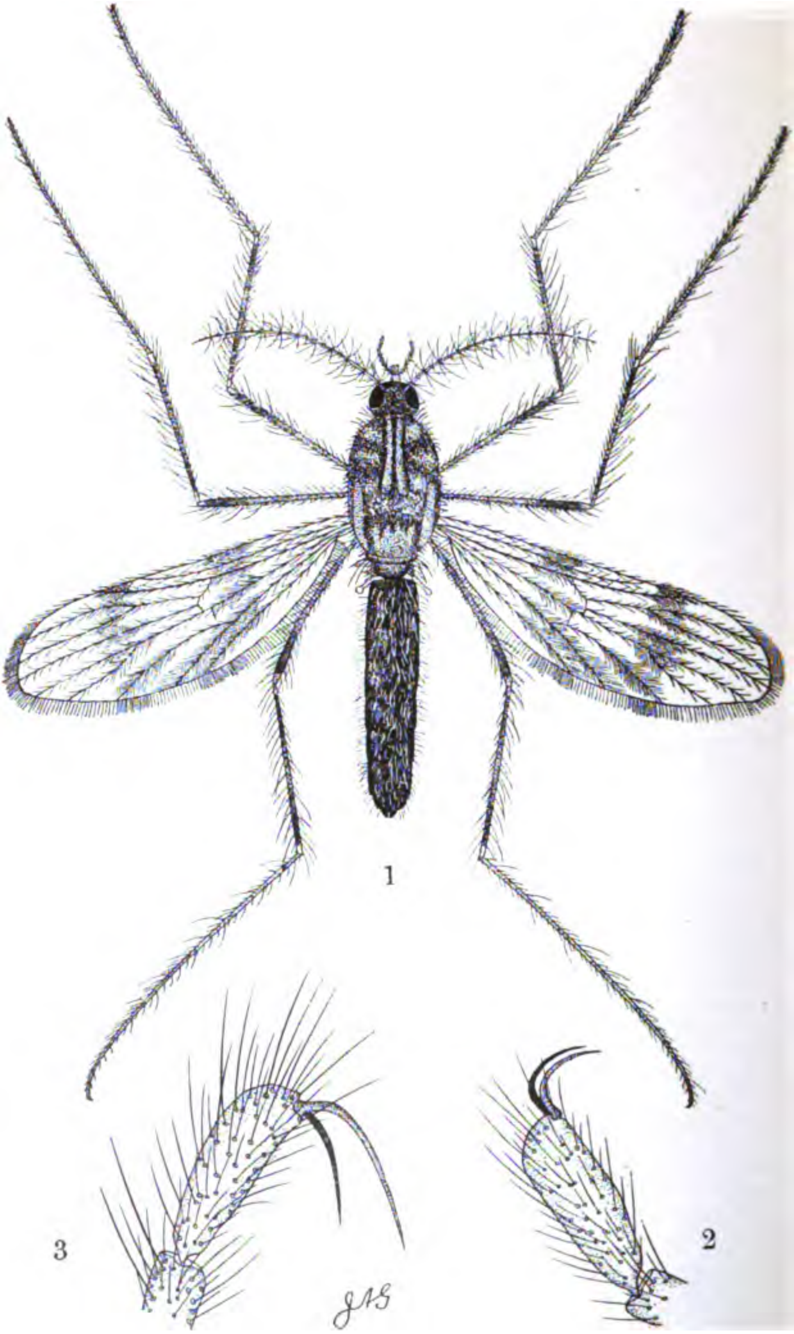

Figure 114.

Corethrella brakeleyi: 1, female adult; 2, anterior, and 3, posterior claws of male: all enlarged. (Original.)

Lahaway was not put on the bogs until October or November and it is unlikely that the larvæ hatched after that time. It is equally unlikely that there was any oviposition by hibernating adults early in March and the alternative seems to be a winter egg hatching with that of *canadensis*.

CORETHRELLA BRAKELEYI, COQ.

Brakeley's Corethra.

This is the smallest mosquito occurring in the State. The thorax is marked by four stripes, the median two edged with very dark brown, which give the anterior part of the thorax a three-striped appearance. The abdomen is unbanded, but has many yellow hairs scattered over the surface. The legs are hairy, the tarsi yellow, the femora and tibiæ brown, with dark shadings near both ends of tibiæ and the apical end of the femora. The wings are crossed by two blackish bands.

Description of the Adult.

This very small mosquito, which is shown on plate figure 114 with some structural details, measures 1.5–2 mm.,=.06–.08 of an inch in length. The head between the widely separated eyes and the occiput is dark brown without markings, save for a faint yellowish border to the eyes. The proboscis and palpi are brown, the latter five-jointed and similar in form to the other species of *Corethra*. The antenna in the female is very long and pale yellow in color, with the basal joint brown, the base of each joint succeeding the first which is very large and globular in form, is elongate, swollen and set with very long bristles at the base; other shorter hairs are scattered over the surface without regularity. In the male the antenna is the same as the female in size and color, but the hairs are long and very dense.

The dorsum of the thorax is brown, marked with several large, grayish confused spots, and two grayish median stripes, which extend backward from the anterior margin to the middle, and are margined with very dark brown, giving the thorax the appearance of having three stripes, two other grayish, longitudinal stripes are on the basal half, one on each side. The pleura are uniformly brown. The legs are covered with long hair. The femora are brown, becoming very dark toward their apices, but are yellowish at the knee; the tibiæ are dark brown, paler in the

central part and yellowish at the extreme ends while the tarsi are wholly yellow. The claws of the male anterior tarsal joint (fig. 114, 2) are simple, very slender and slightly unequal; the mid and posterior, as are all the claws of the female are equal, simple and very slender. The wings are rather broad, the veins clothed with long yellow and blackish hair-like scales, the blackish ones forming two broad transverse bands, the first, one-third from the base; the second, two-thirds from the base; near the posterior margin of the wings the veins are more or less clothed with blackish scales, so as to connect the cross bands. The fringe is white, with a blackish portion at the posterior end of each cross band and another at the apex of the wing.

The abdomen is very dark brown, with numerous yellow hairs scattered over the surface.

Habits of the Adult.

Practically nothing is known of the habits of this little mosquito except that it does not bite because it cannot. Its very small size makes it difficult of recognition in general collecting, hence all our examples are bred specimens. So far as I am aware all the known examples are from Lahaway or Delair, and the species may be ignored from the economic standpoint.

Description of the Larva.

The larva, with the under side of the head greatly enlarged, is illustrated on plate 111, 6. When full grown it averages between 3–4 mm., = .12–.16 of an inch in length, exclusive of the anal siphon, and is of a rust brown color, except for narrow, white, transverse lines which cross the thorax and abdomen. The head is much broader than long, rounded at the sides, slightly excavated before the insertion of the antennæ and flat in front; on each side a transverse row of about twelve short spines, directed anteriorly. The antennæ are situated close together on prominences in the anterior part of the head, and project laterally; they are moderately long, almost straight, with three long curved and one very short spine at the apex. The figure of the under side of the head shows the mandibles and mentum. The mandible is rather stout and chunky, provided with stout teeth at its apex, and a few spines on its dorsal surface; a curious fan-shaped arrangement of flat spines is also attached to one of the

sides. The mentum is very broad and unlike *Culex,* is joined with a suture to the ventral sclerite of the head; on its anterior margin are six to eight large teeth, alternated with small ones. The eyes are small black spots, situated on the sides of the head anterior of the transverse row of spines.

The thorax is white at the neck, and with two narrow white stripes crossing the dorsum, the posterior one divided centrally. It is a little broader than long, with six lateral tufts of rather long hair, the anterior two tufts small, the posterior ones larger and issuing from pointed fleshy processes.

The abdominal segments are transversely oblong in the anterior part, becoming very narrow posteriorly; the lateral two tufts in the first two segments arise from acute processes like those of the thorax, the succeeding ones shorter and smaller, arising from only slight prominences which diminish in size posteriorly. Two transverse white lines on each segment, cross the abdomen near or at the connecting sutures, and a small brown spot is enclosed within. The seventh segment bears the anal siphon which is about two and one-half times as long as broad, with sides parallel their entire length and a few curved spines at the apex. The ninth segment is slightly longer than broad, with a double dorsal tuft of long hair and a scant ventral brush of equally long hair. The tracheal gills are very short, much less than half the length of the ninth segment.

Habits of the Early Stages.

The larvæ of this little species were first found at Lahaway by Mr. Brakeley and myself, June 1, 1901, in a cold spring pool. They were utterly unlike any other mosquito larvæ known to me and yet seemed to be essentially Culicids. From the prominent head Mr. Brakeley dubbed them "Bull-heads"; from the shape I called them "triangles." These specimens were kept alive for a few days only and were very sluggish. July 27th, Mr. Brakeley found a little group of them along the shallow edge of a lily pond among the grasses and some of these pupated on the 28th and 29th, forming a pupa as odd in form as the larva itself. Unlike all the other Culicids this pupa floated horizontally on the surface, almost motionless and drowned readily; it resembled most nearly the chrysalid of some Lycænid butterfly in miniature, and but for the breathing tubes, would never have been suspected of mosquito affinities. When the adults were obtained, four and one-half days later, they proved to be not only specifically but

generically different from anything theretofore known. Additional specimens were found in small numbers until late fall, and it was suspected that it hibernated in the larval stage. It was not until February 9, 1903, however, that Mr. Brakeley positively determined this point by finding nearly full grown larvæ in icy swamp pools. Though there is no definite evidence, it is probable that the species is predaceous in habit, but what its food may be is unknown. Whatever its prey, the capture is not due to any activity of the *Corethrella* larva, for a more sluggish creature it would seem to be impossible to find.

Figure 115.

A typical breeding pool on the Newark marsh. (Original.)

PART IV.

Local Problems and Surveys.

EXPLANATORY.

It is manifestly impossible to report within reasonable limits upon all the areas that were investigated during the three seasons through which this study extended. Whenever a request was received from any municipality, improvement association or even an individual, concerning any specific area, it was usually heeded and information was furnished covering the conditions. In most cases the common house mosquito was in fault and the remedy easy; to report such cases would add nothing to the general knowledge.

It is intended, however, to cover those well defined larger areas which were more thoroughly explored and whose treatment would affect a considerable area or population. It is also intended to demonstrate in this way how small a territory it is really necessary to deal with in some of the areas that had been considered most dangerous. Finally, the intent is to show how extensive our explorations really were and how large a portion of the State was tramped by the collectors and investigators connected with this study.

Examples of work done in specific areas by individuals or asociations not connected with this survey are also given as illustrations of what may be accomplished by local organizations.

CHAPTER I.

THE NEWARK BAY PROBLEM.

a. THE NEWARK PROBLEM.

This divides naturally into two parts, the salt marsh area and the city breeding places. For several reasons the work at Newark was done much more thoroughly than elsewhere. *First,* the Board of Health primarily and the city authorities following

them evinced a real desire to do something. *Second,* Mosquitoes were about as abundant and troublesome as anywhere in the State and successful work there would convince a large number of persons of the practicability of mosquito control over large areas. *Third,* Mr. Brehme lives in Newark, is well acquainted with the city and was able to put in all the odds and ends of time when not engaged in other specific investigations in hunting out or watching local breeding areas. *Fourth,* Newark is a modern, growing city, where interferences with natural drainage are constant, and where also improvements were tending to remove unsanitary conditions that favored mosquito breeding.

The conditions at Newark are duplicated elsewhere and form an object lesson both as to how mosquito breeding places may be created by the march of progress and how subsequently they are again abolished by further work.

In the City.

Branch Brook Park, in the northern part of the city is not only the finest park in Newark, but one of the best planned of its kind in the United States. Evening concerts are given there during the summer, but enjoyment of the music is sadly marred by the swarms of mosquitoes that are nearly always present. The Park lake gets the credit for breeding these pests, but not one of the several examinations made developed a sufficient number of larvæ to account for the adults. From captures made it appeared that a considerable percentage of the insects were from the salt marsh; but there was also a very large percentage of *pipiens,* which must have a local origin.

At my suggestion Mr. Brehme examined the catch basins of the drainage system and then the mystery was explained. The Park has about one hundred of these overflow basins, which take the surface water coming down the slopes. All of these basins are in bad condition and in many of them the pipes are so badly choked that it is almost or quite impossible for the water to run off. There is some water in all the basins at all time, and so they form most excellent breeding places throughout the summer. One brood was checked by pouring a little oil into each basin; but later broods were allowed to develop. On one occasion, after a very heavy downpour, some of the basins refused to act altogether and considerable pools were formed over them. The obvious remedy, of course, is first to clean out the pipes and basins and then at intervals of about ten days during the summer to pour into each basin about two or three ounces of kerosene or fuel oil.

Another smaller breeding place is on the south side of Fifth avenue opposite the park and on the west side of the Morris Canal. This is the remnant of an old pond and needs only a few loads of dirt to fill it.

The old sunfish pond on Bloomfield avenue, which was a very bad breeding place for a variety of species, is now being made forever safe with ash filling. But on the south side of the avenue is another bad place, which the very filling above referred to will have a tendency to increase in extent. A small, spring-fed brook runs through this place and into the sunfish pond. When this pond is filled and the drainage blocked, this little brook must spread out to cover a surface great enough to absorb the water. The stream is not large, but it has no outlet, and the surface water from the avenue is in addition led into the depression. Just what disposition should be made of this place is not clear. *Culex cantans, canadensis, pipiens* and *sylvestris; Psorophora ciliata* and the species of *Anopheles* all breed here and the place is therefore dangerous at all except the very driest times.

Along the east side of the Morris Canal between the north end of Branch Brook Park and the Greenwood Lake Branch of the Erie Railroad are a few bad breeding places formed by seepage through the canal banks. Coming from this source the water supply is almost continuous, and this carries with it also the constant breeding. The depressions in which this water lodges should be filled or the canal bank improved.

A place which breeds millions of *C. pipiens* each year is an old sand pit at Thirteenth avenue and Twentieth street. Rain water drains into this place and evaporates very slowly; so there is some water there at almost all times, forming an ideal place also for *Anopheles* in late summer. Filling seems to be the only remedy indicated here. A similar place is at Seventeenth avenue and Nineteenth street, where some fifteen cart loads of dirt would effect a cure. From these places and from the swamp on Thirteenth and Fourteenth streets, West Side Park gets its main supply of mosquitoes. This swamp area is to be filled in during the winter of 1904-'05, the swamps between Eighteenth and Springfield avenues and Fourteenth and Sixteenth streets are already filled and this will very materially lessen the number of mosquitoes in that section of town. Other breeding places that are in process of cure are on Springfield avenue between Sixteenth and Seventeenth streets, where low lots are being graded and breeding holes filled.

Another swampy area which breeds many mosquitoes is southwest of Woodland Cemetery. It is proposed to run a street

through this swamp which will probably make matters worse for a time, until the place is graded for building lots.

A few bad places are to be found on Osborn Terrace near Runyon Avenue. These are low lots into which water drains and lies for a long period, giving ample time for two or more broods of *pipiens* after a moderate rain. On 18th Street between Avon and Clinton Avenues are several bad swampy places that breed many mosquitoes. Here filling seems to be the only remedy unless, when 18th Street is sewered, the swamp is drained into it. That would be the most practical measure if, as I am informed, a sewer is contemplated in the near future.

Along the West Newark branch of the Pennsylvania Railroad freight line is a spring, the water from which runs along the west side of the track in a poorly constructed gutter. The drain is irregular, there are many stoppages forming pools and here the insects breed continually. Mr. Brehme reports at least ten inspections and each time every pool was packed full of larvæ of *C. pipiens* and *restuans*. If this gutter were cleaned and properly graded it would carry the water perfectly and would render breeding impossible.

A very bad place for *C. pipiens* is on the north side of the Newark branch of the Central Railroad just west of Brill Street. Here an old ditch was cut off by the railroad, leaving a trench about 150 feet long in which water remains at almost all times and where mosquito larvæ develop almost continuously. Only filling will answer here, to bring the ditch to the general surface level.

Opposite the trolley barns of the Newark and New York line on East Ferry Street, is a bad breeding hole for *C. pipiens;* but that is in course of being filled and no breeding will go on there in 1905.

It is not pretended that the above is a complete record of all places within the Newark City limits where mosquitoes breed. But it does enumerate the larger areas from which great numbers spread out over a considerable vicinage. It shows how some of the breeding places were formed, how others have been kept up and how, in normal course, a large percentage are in process of elimination. It indicates also what may be done to hasten a better condition and that a little carelessness or lack of appreciation of consequences on the part of the municipal body charged with the care of parks, may result in materially impairing the comfort of those resorting to them for recreation.

This part of the problem is fully within the power of the Board of Health and will not, I am sure, long lack abatement.

Figure 116.
Rear view of the ditching machine; shows how the sod is taken out and drawn to one side. (Original.)

On the Marsh.

The salt marsh lying within the limits of the City of Newark covers an area of about 3,500 acres; beginning on the Passaic River at a point about one and one-half miles east of the Pennsylvania Railroad crossing, and extending southwesterly to the mouth of Bound Creek where it empties into Newark Bay. Bound Creek is the dividing line between Newark and Elizabeth, all to the south of the creek belonging to the latter city. This gives a length of approximately eight miles and an extreme width of nearly three miles, though the width varies continually owing to the irregularities of both the coast and the highland line. This marsh area has been under observation since 1902 and we estimated that some 500 acres of it was mosquito breeding area of the most virulent type.

The marsh is cut into sections by railroads and creeks which materially influence drainage. The Newark and Elizabeth line of the Central Railroad runs from its point of divergence from the New York line lengthwise through the marsh from northeast to southwest on a solid roadbed which completely cuts the drainage of the western half of the marsh from the river and bay. The line is cut only at the Peddie Street sewer, Maple Creek and Bound Creek, and all the surface and other waters of the areas west of this road must find their way to the bay by means of these three streams. The Newark and New York branch of the Central Railroad crosses the marsh on a solid embankment at nearly its narrowest point about a mile south of the northern border. The Lehigh Valley Railroad freight line crosses the marsh in the same way, also on a solid embankment about two and one-half or three miles south of the northern border of the marsh. Nearly a mile south of that the Peddie Street sewer crosses the marsh in a straight line of about three miles from city to bay. This sewer is nearly or quite twenty feet wide and has banks from three to four feet above the ordinary marsh level. The whole area was tramped again and again by Mr. Brehme, and I made numerous visits to it myself to verify Mr. Brehme's observations. Nevertheless the following is based almost entirely upon Mr. Brehme's report.

The area that lies between the north end of the marsh and the Plank road was closely inspected in 1903 and one small breeding area was found and marked. In the spring of 1904 it was found that this area had become overgrown with cat-tails which were so dense at the time of inspection that no mosquito larvæ could

breed there. It was a case of natural elimination of a breeding area.

The territory between the Plank road on the north and the Newark and New York Railroad on the south is in good condition so far as mosquito breeding is concerned. Numbers of natural ditches or creeks run through here and there is always a good supply of fish in the pools. Cat-tails are also springing up all over this place and are taking possession.

The area between the Newark and New York Railroad and the Lawyers ditch is one solid bed of cat-tails in which no wriglers were ever taken no matter how close the search. Killies are to be found in numbers all through this place and it is perfectly safe so far as mosquito breeding goes.

South of the Lawyers ditch and between it and the Lehigh Valley Railroad, a distance of about a mile, was one of the worst breeding places on the Newark meadow.

In 1903 an experiment with machine ditching was tried on the territory between the Lawyers ditch and the Balbach or Hamburg Place road. The worst parts of the meadow were picked out and between 35,000 and 40,000 feet of ditches were cut with the True ditcher. The ditches were six inches wide, two feet deep, and drained perfectly from the beginning. They laid that piece of rotten meadow so dry that the grass that grows there can now be mowed by machine, where before the hay could only be cut in winter because no horse could get over the marsh in summer.

The work was so obviously successful that the Board of Health asked and finally obtained fron the Common Council an appropriation of $5,000 to complete the mosquito drainage of the meadows. Work was begun at the place where it was left off in 1903 and the remaining danger points between the Lawyers ditch and Hamburg Place road were finished. Work was then started on the south side of Hamburg Place road toward the Lehigh Valley Railroad, at a time when the second brood of mosquito larvæ were just hatching all over the meadow. The work of sixty-five men and the machine proceeded so fast that, before one mosquito of this second brood had time to hatch and get away, every pool was drained and the larvæ and pupæ were killed. Many ditches were cut here and the sods taken out were used to fill the old breeding holes.

It might be interjected here that all the work done was under the general direction of Mr. Brehme, whom I detailed for that purpose, and he deserves credit for the excellent judgment he displayed in obtaining good results under generally difficult conditions.

The area that lies between Hamburg Place on the north, the Lehigh Valley Railroad on the south, the Newark and Elizabeth Branch of the Central Railroad on the east, and the Waverly Branch of the Pennsylvania Railroad on the west is an irregular square covered with water which has no outlet whatever. It was originally drained by Pierson's Creek, but when the Lehigh Valroad laid its tracks across the marsh it made a solid embankment, cutting off the head of the creek and leaving a large area absolutely without drainage, for the other boundaries mentioned are also solid dams or roadways. In this area is also the beginning of a ship canal which was started in the seventies, but never completed. Fortunately, when the creek was cut off, the water bodies were well stocked with fish and these have continued to breed in what is now a stagnant pond kept down only by evaporation, and into which cat-tail and duckweed are crowding from the edges. These natural conditions—the cat-tails and fish supply—prevent mosquito breeding in what looks like a very bad territory.

A similar though much smaller area on the east of the Central Railroad was blocked off in the same way by the Lehigh Valley dam, is also well supplied with fish and these have multiplied to such an extent as to penetrate everywhere as far as the water itself covers the ground. There is no danger whatever of mosquito breeding at this point.

A very bad breeding area was found around a little island of highland just southeast of the junction of the Central and Lehigh Valley Railroad. Ditches were cut here and led to tide water taking off all surface water and admitting the killies which now extend to the very ends of the ditches. All the holes on the highland were filled with sods and breeding is now impossible.

The remainder of the space east of the Central Railroad to the bay, between the Lehigh Valley Railroad and the Peddie street sewer is largely overgrown by cattails, or flooded with water in which fish are abundant. No larvæ were ever found here at any time and there seems to be no possibility of their developing under present conditions.

South of the Peddie street sewer to Maple Creek, extending east from the Central Railroad to Newark Bay, was an extremely bad breeding area. Many ditches were cut here, and some were run from the Peddie street sewer into Maple Creek. Through these ditches the water runs like a mill race and cleans out all the connecting ditches. Fish are plentiful, most of the old breeding pools are directly connected with the ditches, while those too far away to drain quickly are filled by the sods taken from the

ditches. This, formerly one of the largest mosquito mills, is now almost absolutely safe.

The last of the spaces east of the Central Railroad and extending to Newark Bay is between Maple Creek and Bound Creek. Breeding areas were plentiful here and ditches were run between Maple Creek and Bound Creek to serve as outlets for ditches run to drain the chief breeding areas. The tides run clean through these cross ditches into the connecting ditches and fish are found in them everywhere. All the sods have been removed and used to fill up the deeper holes or those so small and remote as not to drain easily. The ground is now clear, free from water and believed to be mosquito safe.

West of the Central Railroad, between Bound Creek and Maple Creek, a swampy area extended to a small branch of Bound Creek near the highland. Though this was not a bad breeding area ditches were nevertheless cut to make the place entirely safe, and the drainage scheme works well. West of the small creek already referred to, to the Pennsylvania Railroad at the edge of the highland is a low cat-tail marsh, more or less flooded by the tides from both Bound and Maple Creeks and with killies in every open pool. No mosquito larvæ were ever found and it is believed that they cannot breed here.

The next block west of the Central Railroad is between Maple Creek and the Peddie street sewer, and extends to a wide ditch that runs from Maple Creek to, but not into, the Peddie street sewer. The ditch is bulkheaded from the sewer, hence really forms a branch of Maple Creek. This territory contained a number of bad breeding places which were all drained and the ditches now work well.

West of the wide ditch and extending to the Pennsylvania Railroad the area is covered with cat-tails, and all the pools are full of fish. It was deemed desirable, however, to make another connection between the wide ditch and Maple Creek to give the fish a better chance to get in and out of the pools with connecting ditches. It is always possible that an unusual tide or very heavy storm may carry water almost anywhere on this low marsh and if any depressions not readily noticeable are filled in this way, it is desirable to have the killies present to go in with the water. In all cases, therefore, it has been kept in mind to facilitate the running of fish and their ready entrance into depressed areas.

There remains now the stretch west of the Central Railroad, extending between the Peddie street sewer and the Lehigh Valley Railroad, to the highland. These lateral boundaries run

Figure 117.

Cleaning out a line ditch: this often takes more time and labor than cutting new ditches (Original.)

nearly parallel to the Dead Creek which is now used as an outlet for the Tenth ward sewer. At this point the Lehigh Valley Railroad curves to the south and meets the Peddie street sewer at its crossing with the Pennsylvania Railroad as the apex of a triangle. This triangle is a solid cattail area in which the open water is completely covered with duckweed, making it impossible for mosquito larvæ to breed.

There are some breeding places along the edge of the highland norh and west of the Lehigh Valley Railroad, but these are in process of elimination by being filled with ashes, etc. So the space from the Pennsylvania Railroad to Frelinghuysen Avenue, south of the Lehigh Valley Railroad, is made safe by the work done in building the Pennsylvania Railroad freight station.

There remains an oblong into which there is an intrusion of highland crossing the Lehigh Valley Railroad and extending almost half way across to the Peddie street sewer. On this highland is the sewer pumping station which forces sewage through a box sewer diagonally across the marsh beneath Pierson's Creek, the Central Railroad dam, Peddie street sewer and into the bay at the mouth of Maple Creek some 700 feet from shore. This sewer is in bad condition and the sewage flows to a great extent over the meadow which is low and not much above tide water. The railroad dams are three or four feet above the marsh level and the Peddie street sewer bank is almost equally high, hence this low area is enclosed by high banks. Originally it was drained by Pierson's Creek, which was then a branch of Maple Creek and a clean tidal stream. Its head was cut off as already stated by the Lehigh Valley Railroad. Its mouth was cut off by the Peddie street sewer, to which it is now a tributary, and instead of clean tide water and fish it now carries sewage and mosquito larvæ. It crosses the eastern part of the oblong not far west of the Central Railroad and as a whole parallel with it and to this creek all the drainage of this depressed area must come. There is a tide gate or sluice at the entrance of the Dead Creek into the Peddie street sewer; there is none at the point where Pierson's Creek enters into the sewer. The former is in bad condition and practically useless, as the water gets under and around it everywhere. The result is that whenever there is an extra high tide the sewer water is forced over the low areas in the marsh and whenever a heavy rain brings down an extra amount of surface water it overflows and backs into the creeks and over the meadow. When once there is an overflow the drainage out is very slow, because there is only the Pierson

Creek outlet, and that works only during he period between the last of the ebb and the first of the flood.

The northeast corner of the oblong between the Central Railroad, Lehigh Valley Railroad and the pumping station is an almost solid cat-tail area with all the open water so completely covered with duckweed that wriggler life is an impossibility. Along the line of the Central Railroad is a deep ditch into which the area between the box sewer and the railroad was drained by means of ditches. This converted what was previously a very bad breeding place at all times, into one that is normally safe. It is only when, after a very high tide, the back water keeps the meadow full for a week or more that any breeding can occur here. Such conditions happen only in early spring and late fall when the breeding is normally slight.

The space between the sewer ditches, Pierson's Creek, the railroad and the box sewer is fairly well drained except for about 500 feet from the box sewer which is here broken and from which there is a continuous flow over the marsh.

As for the rest of the area a considerable portion is covered with cat-tails; there are some deep ponds in the northwestern section very fully covered with duckweed, but there are also plenty of surface pools in which mosquito larvæ breed freely. Many ditches have been cut here but the fall is so slight and the period during which an outflow is possible is so short that the ditches themselves tend to become breeding places even when the surface pools drain into them. No fish run up the sewer ditch and there are none anywhere on the meadow; conditions are absolutely too foul for them.

The remedy is obvious enough and consists of three tide gates and a new or at least a repaired box sewer. So long as sewage is continually discharged over this meadow some breeding places are bound to exist. The tide gates at Dead Creek and Pierson's Creek will keep the Peddie street sewer water from the meadow and will keep up a constant outflow even if only for a few hours each day. With only the normal surface water to dispose of, the ditches would work well enough and if the sewer influx can be stopped they could be stocked with fish. The third gate should be at the Central Railroad ditch crossing to prevent the tides from getting into the meadow at that point. The ditch is long enough and wide enough to hold all the drainage between tides and the outflow would then be continuous.

It will be seen that this Newark marsh problem was an unusually complex one, and one that would not be likely to recur in the same way at any other point along the coast. Nevertheless on

the entire 3,500 acres of marsh not one hundred acres remain on which there is any breeding whatever, and that is dangerous only in a few places and under certain abnormal conditions.

Including old ditches cleaned out, about 360,000 running feet of ditches have been dug on the Newark marshes, partly by machine and partly by hand, and if the work is not entirely successful, that is due to the defects pointed out and which were not included in the drainage scheme.

It is a safe prediction, I think, that Newark will have no early brood of mosquitoes in 1905, comparable with the invasions of 1903 and 1904.

b. THE ELIZABETH PROBLEM.

Elizabeth was the first large city of the State to begin a systematic mosquito campaign and a somewhat full study of the results obtained, of the money expended and of what yet remains to be done seems to be justified.

The work during 1902 was in charge of Dr. Wm. F. Robinson, whose report is reprinted here, omitting all descriptive matter. During 1903 and 1904 it was in charge of Mr. Louis J. Richards, the Health Officer, who supplies a concise statement of what has been accomplished. I have been in touch with the work throughout the entire period, and the use of "killies" in cisterns was adopted at my suggestion. Especial attention should be called to that part of Mr. Richard's report which speaks of the results obtained from work under the Duffield amendment to the general health law. When the usefulness of this provision is fully appreciated, city, town and village breeding places will exist only because local boards of health want them there.

Mr. Richard's report is as follows:

In 1902 about $500 was raised and spent by a Citizen's Committee, organized in April and composed of sixteen or more representative citizens and public officials. The work done was temporary and consisted of oiling and, in the vicinity of areas treated, resulted in a diminution of numbers of mosquitoes.

In April, 1903, the sum of $1,000 was appropriated by the City Council, of which $700 was spent in permanently draining very nearly ninety acres of salt meadow along and near the mouth of the Elizabeth river. In this work part was done by hand and part by machine. In the hand work a sort of bog-saw was made to cut the sides of the ditch, and also heavy pieces of iron, with sharpened edge and iron handle, to cut off the sod as sawed out. The machine was much more economical where the ground would admit of its use. $92.50 was spent in having 10,000 pamphlets on mosquito extermination, by Dr. W. F. Robinson, printed for public distribution, especially in the schools of our city.

This ninety acres is relatively small to the large extent of our whole meadows, but is an area which contributed more than its corresponding ratio

of mosquitoes to Elizabeth, owing to its greater proximity. The results of this work, which were not so appreciably felt last year, have been quite apparent this season. The remainder of the appropriation was used for oiling, etc., within the city.

In 1904 no money has been appropriated for permanent work, but enough oil has been used to treat all catch-basins and a few pools of water which could not be readily drained this year.

We have, however, taken advantage of the amendment to the Public Health Act in relation to mosquito-breeding areas, and numerous low-lying lots have been filled in, or drained, and one inland swamp, requiring several thousand feet of ditching, has been drained. This has all been done at the expense of the owner of property treated.

It is too early to state whether enough can be appropriated for 1905 to drain our remaining marsh area, but every effort will be put forth to bring the matter forcibly to the authorities. The use of oil for catch-basins and fish for cisterns will certainly be continued.

(Signed) LOUIS J. RICHARDS,
Health Officer.

The following is the report referred to by Mr. Richards:

Report of the Study of the Mosquito Pest in Elizabeth, N. J.

BY DR. WM. F. ROBINSON.

Man has many ills that disturb his mental peace and bodily comforts. When disease visits him he quietly accepts the inevitable and puts his faith in the attending physician. If a pest attacks his fruit trees, destroys his harvests, or kills his pigs and cattle, he spends large sums for immediate relief. But it remains for a future philosopher to explain why he will submit for centuries to a pest so widely spread as that of the mosquito, with no greater protest against its persistent attacks than an impatient slap, or the barricading of his house with wire meshes.

The study of the mosquito has engaged the attention of numerous scientists for several years, and ways and means have been gradually evolved for ridding communities of this pest and nuisance.

At the April (1902) meeting of the Agassiz Society for Scientific Review I read a paper on "How Mosquitoes Transmit Disease and What We Should Do to Rid Ourselves of the Pest." This was published in the local press and attracted so much attention in our community that the *Elizabeth Daily Journal* generously gave the funds for starting a practical investigation and experiment in this locality. The Civic Federation sent $50, with encouraging words, and the following gentlemen, Messrs. A. B. Carlton, A. D. Mulford, F. H. Davis, C. B. Orcutt, Fred. H. Levey, John C. Rankin, Jr., P. J. Ryan, George W. Rogers, Frank Bergen, Charles H. Moore, W. W. Willett, P. H. Gilholly, George E. Dimock, George T. Parrot, A. F. Young and Dr. V. Mravlag, gathered at a meeting held in the parlors of Comptroller Carlton, gave $25 each to complete a fund for carrying the work forward during the season. Later, an additional sum of $10 was sent to the treasurer by Mr. Benjamin Whitley. The above-named gentlemen effected an organization, with Mr. A. B. Carlton as president, Mr. C. C. McBride, secretary-treasurer, and Mayor Ryan, Comptroller Carlton, ex-Mayor Rankin, A. D. Mulford and Hon. George T. Parrot, Executive Committee.

The "Downtown Taxpayers' Association" invited me to speak before them and generously offered to contribute funds to the cause, if needed, as did many other citizens, but a unique feature of the history of this movement is that no funds were solicited and the treasurer's report will show a balance on hand.

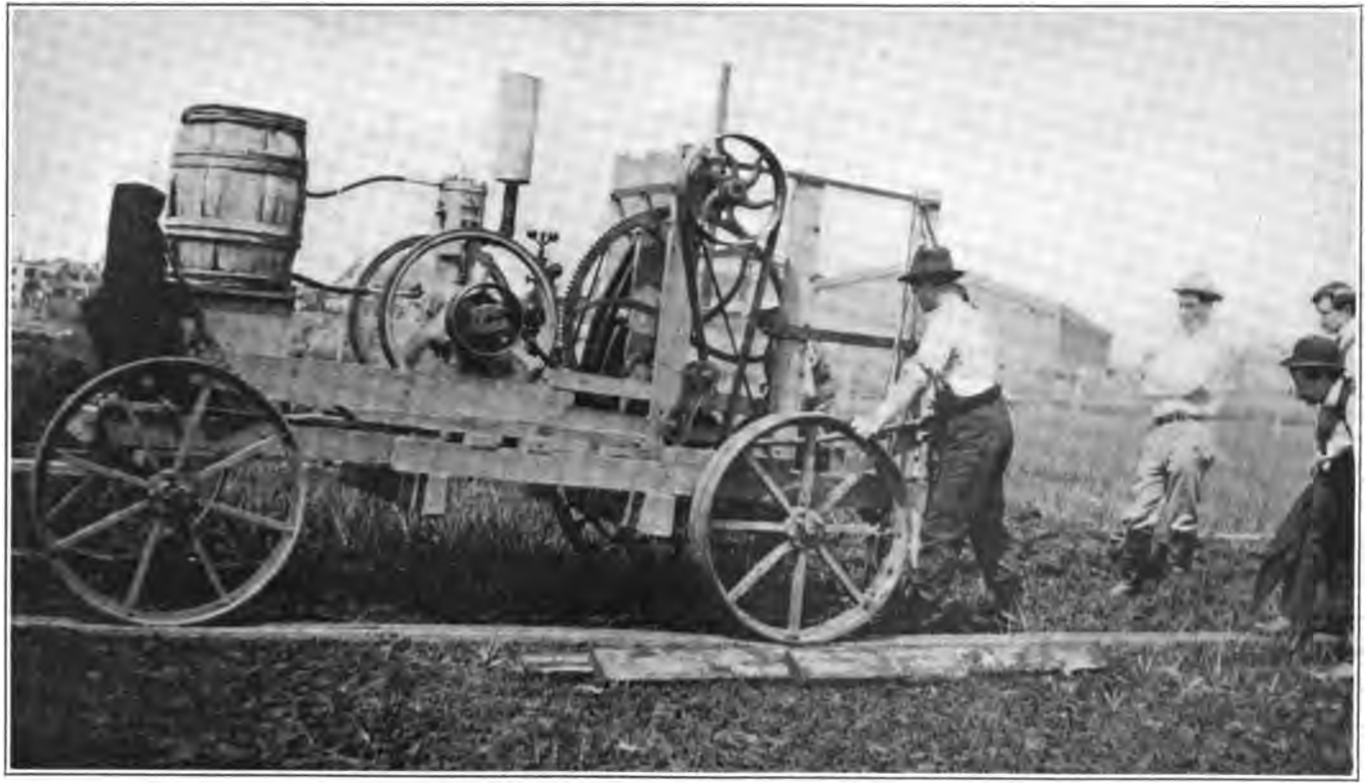

Figure 118.

The ditching machine on the Elizabeth marsh; Mr. Louis J. Richards (with folded arms) in command. (Original.)

At the May meeting of the Board of Education, Commissioner Coleman offered a resolution, which was unanimously adopted, asking me to address the public school teachers upon the subject, and directing the principals to see that each child in his or her school was given simple instructions to enable it to find and destroy all mosquitoes that might be found breeding upon his home premises, or the immediate vicinity.

With this impetus to the cause and the frequent and cordial support of the press, especially that of the *Elizabeth Daily Journal,* I began work at once to form a brigade for active work. It was not my intention at first to do more than start several men to oiling the stagnant pools lying within the city, and found to be infested with the larvæ, or wrigglers, of mosquitoes, but as the investigations and experiments proceeded they grew to such proportions that I found them absorbing every moment I could spare from my other duties during May and June and most of the summer vacation.

WHAT WAS DONE.

Unfortunately, many of our people thought the brigade was attempting the immediate extermination of the mosquito, notwithstanding the frequent statements made in the press that but little immediate relief could be expected until the whole problem, covering not only the stagnant pools in and around the city, but also that vast area lying along the Sound, was thoroughly studied. This study has been made by the brigade within our city, and most extensively and proficiently by Dr. John B. Smith, State Entomologist, in all the salt meadows lying within our immediate vicinity, and we can now say with a degree of confidence that we scarcely hoped for at the outstart that relief from the mosquito pest for this community is certainly in sight, if the proper officials are authorized, during another season, to execute the plans and suggestions herein to follow in this report.

Our local study has consisted of experiments with four different oils on the smaller pools and street sewer-basins; the placing of small fish in permanent pools and, through the aid of Health Officer Richards, the draining of several useless and dangerous sheets of water.

A microscopical specimen of each species found in the larval stage was prepared and will be preserved for the purpose of identificaton by those who may continue this work in the future. It is very essential that each species should be identified as soon as it appears ir season, so that intelligent treatment may be directed toward its destruction, if known to be of the noxious type. It is in this particular that many communities have failed where the work of extermination has been attempted.

As so many friends who are interested in this movement have frequently remarked upon the meagre outlay of money, it may be well here to make the following statement: It was my intention at the outstart to make every dollar go as far as possible, in order to demonstrate that this kind of work need not be so expensive as many people believe it would be.

Instead of purchasing a horse and wagon and engaging two or more men for the season, as advised, I arranged with a liveryman to pay him $2.50 per day for a team, while in service, and fifteen cents per hour for labor, while employed. Then, instead of making my frequent tour of direction and inspection in a carriage, as our good Mayor suggested, the wheel and trolley car were found to be more convenient and much less expensive. We also avoided the mistake of employing ignorant labor to pour oil upon what was presumed to be troubled waters, teaching our young man to know the aquatic form of the mosquito when he saw it, and to make periodic trips of examination, so as to know that a pool was infested with larvæ, or pupæ, before oil was applied, thus saving time, labor and material. My own services, of course, were voluntary. * * *

SPECIES FOUND IN ELIZABETH.

It is my conviction that mosquito extermination will not be successfully prosecuted in any locality without the employment of intelligent labor. That is, there must first be an identification of the species in the larval state to know best how to treat them, and second, the men who spray the oil should be trained to know if the water is infested with mosquitoes before they proceed to treat it, else there will be a waste of time and material, because a man who is wholly ignorant of the presence of an object he is sent forth to kill cannot best serve the ends for which he is employed, and the possibilities are that he may do quite as much harm as good, because he is working in the dark.

I have found eight different species in this locality during the season and have mounted them in their larval state in microscopical slides, which will make future identification of these species quite simple. They are as follows:

*Culex canadensis,**	*Culex pipiens,*
Culex territans,	*Culex sollicitans.*
Culex cantans,	*Culex sylvestris,*
Psorophora ciliata,	*Anopheles punctipennis.*

Professor Smith, the State Entomologist, has had a man on these meadows all summer, and the remarkable and interesting results of this study of the salt marshes will be shown in a map later in this report. Professor Smith has made an interesting discovery regarding the laying of the eggs of ths species. Upon the occasion of one of my visits to his laboratories in New Brunswick last summer, he gave me a piece of the dried mud, or sod, cut from the meadows several weeks before and asked me to place it in water after I reached home and watch results. This I did, and in less than twenty-four hours the water was swarming with larvæ of *sollicitans.* This means that the eggs are laid in the mud and will lie there probably an indefinite period of time, until submerged with water of the proper temperature to hatch out the larvæ. Professor Smith justly claims that this fact will become an important factor in the methods employed for the destruction of *sollicitans.* As the *sollicitans* do not breed anywhere, except upon the salt marshes, but one method of extermination need be applied to them—that of drainage, and an examination of the map on page 17 will show how easily that may be accomplished, since every infested spot is close to a running stream.

Current literature has come to speak of malaria as the product of the Anopheles mosquitoes, but this statement lacks scientific accuracy, since the name applies to, at least, two different species—the *punctipennis* and *maculipennis.* The latter, without doubt, is the source of malaria, i. e., the *maculipennis* acts as an "intermediate host" for the development of the malarial parasite, when this mosquito sucks the blood from a patient suffering with malaria, but it has not yet been proven that the *punctipennis* serves the same purpose in the development of this germ, and it is the *punctipennis* only that we found in this locality.

I cannot, in this brief report, go into a discussion of the relation of mosquitoes to malaria, but will refer those who may wish to read what the medical scientists of the world have to say on this subject to two articles in the report of the Smithsonian Institute for 1900, by Dr. George M. Sternberg, Surgeon-General, United States Army.

The theory, shorn of all its technicalities and boiled down to a simple statement, is that it is impossible to get true malaria without being bitten by the mosquito *Anopheles maculipennis,* and further, that this mosquito can not transmit malaria to you unless it has previously drawn blood from a malarial patient. The parasite passes with the human blood into the mos-

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* Descriptions are omitted.

quito's stomach, where it undergoes a necessary change (hence, the mosquito is called an "intermediate host"), and thence into the salivary glands of the mosquito. Now, when this mosquito bites another person the saliva, charged with the malarial parasites, is injected into the blood, where they attack the red corpuscles and the victm is soon stricken with the paroxysms known to malaria.

To all who have followed this report with care it will be apparent that the mosquito problem in Elizabeth narrows itself down to the question of means for the extermination of two species of mosquito—*Culex pipiens* and *Culex sollicitans*. The former breeds wherever it can find standing water in pools, ponds, ditches, sewer-basins, rain barrels, cesspools, or tin cans. Most of these places can be destroyed by draining, or filling in; the rest can be stocked with fish, treated with oil, or disposed of by sanitary inspection. The *sollicitans* breed entirely upon the salt marshes, and hence, their destruction is the larger part of the problem, but a thorough study of the accompanying map of Professor Smith's will show you that the whole area of these meadows is not infested with mosquito larvæ, and further, that those portions which lie in close proximity to streams, making drainage a much simpler matter than was anticipated before Professor Smith made his entomological survey.

Newark owns about two-thirds of these meadows and, apparently, breeds more than that proportion of the salt marsh mosquito. Most of the danger spots lying southeast of and adjacent to the city can be drained by lateral ditches leading from Woodruff creek. In Professor Smith's forthcoming report will be shown cuts of a machine that will cut ditches at the remarkably low cost of ten cents per rod. Then nature has supplied a handy remedy in the millions of little fish that fill the streams flowing across these meadows. I made several trips across portions of the meadows last summer, and I never found a larva in water where these fish were living. Therefore, if ditches were cut from the creeks to the inland pools fish would run the whole length of them and keep them entirely free from larvæ. It should be remembered that while draining is expensive at first cost, it is permanent in effect. Professor Smith said to me, in speaking of this locality: "I doubt if $500 would be needed to clean out the entire meadows belonging to your city."* Such a small sum expended upon the meadows, with the relief it would surely afford, could be measured in a few years by nothing short of a thousand-fold return in the valuation of our city's taxable property.

In concluding this report, let me sum up the conditions as follows: A pretty thorough examination of the sources of mosquitoes within our city limits has been made, and they have been found in the ponds, pools, sewer-basins and such temporary places as rain barrels, tin cans, etc. The use of oil and fish have been sufficiently tested to make it clear that when applied to places where water must be left standing they are effectual in clearing out all the places experimented upon. The pools upon the dumping-grounds might be filled in at a little cost by utilizing the dirt and ashes dumped near by. A house-to-house inspection is necessary to insure absolute care on the part of many people, who would otherwise neglect breeding sources upon their property, and the only officials who can do this successfully are those employed by the Board of Health.

No attempt has been made to kill the mosquitoes upon the meadows, but Professor Smith has definitely located them, and says they can be removed by drainage, and he makes it clear with what facility this drainage may be done.

This brings us to the question, "What are we going to do about it?" and this question I leave before the people of Elizabeth for them to make their own answer, believing it will be in the light of wisdom, looking to-

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* This was first impression; the problem is larger than it seemed then. (J. B. S.)

ward the amelioration of a long-suffering public from a most noxious pest. My services have been given to the cause with the hope that outdoor life in summer might be made as enjoyable here as it is in many towns where the mosquito is unknown, and with the many natural advantages of water-front and railroads, our city might become, not only a greater residential suburb of New York, but develop a manufacturing industry second to none in the State. WM. F. ROBINSON.

November 1st, 1902.

Having in hand the reports of what has been done, it will be interesting to read Mr. Brehme's report of the investigations made by him from time to time for the three summers last past:

The area between Bound Creek and Woodruff Creek and the high ground and Pennsylvania Railroad is of considerable extent and looks like a very dangerous piece of ground. Indeed it becomes dangerous at times during the summer when the tides run low and none rise high enough to stock the pools. The early spring tides overflow the banks of both Bound and Woodruff Creeks and with these high tides killies come over and are left in the tide filled pools as the water recedes. Several inspections of the area were made and no larvæ were ever found until midsummer after a spell of dry weather had dried up all the pools and killed the fish which had been left there in spring. After the first heavy shower subsequent to this drying out the pools became water filled and, no fish being then present, the larvæ of the mosquitoes have everything their own way and swarm everywhere. There are many old ditches on this meadow which would be very useful if they were cleaned out and there are two large creeks—Bound and Woodruff—which have good banks and sufficient depth to take any ditches which it might be necessary to run into them. In a favorable season both Elizabeth and Newark get a very nice supply of mosquitoes from this territory.

The next point is the area between Woodruff Creek and the Central Railroad east and west, and Grand Island and Bound Creek, north and south. This place has a number of breeding pools which can be abolished by cutting ditches into Bound and Woodruff Creeks. There are many large ponds and pools on this stretch; but all are stocked with fish. Old ditches cut many years ago run to these ponds and pools. They would be working to-day were the railroad ditches not filled. Some eight or ten years ago an enormous flood tide swept in from Newark Bay across the Central Railroad bed and washed out the embankment, filling the ditches with stones, cinders and other debris. The roalroad rebuilt its embankment with new material and left the old where the water placed it. The ditches were never reopened and the natural drainage of this meadow area

Figure 119.

A hand-dug main ditch on the salt marsh. Into this, the narrower, or machine ditches are run. (Original.)

was effectually blocked. Before that flood this was a good meadow and hundreds of tons of hay were taken off every year; but now it is water-soaked, a regular quagmire upon which it is unsafe to venture at times, no hay can be cut on it and mosquitoes breed almost constantly in many places. To redeem this area the railroad ditches must, first of all, be reopened and the natural drainage restored. After this has been left for a time the surface will work back gradually into a condition that will permit of its better ditching. As it stands now the meadow is altogether too soft to hold a ditch and is like liquid mud under foot after a rain or extra high tide.

The area between Bound and Oyster Creeks and the Central Railroad is also dangerous. Near the Bound Creek it is not so bad and only a little work is required to make it safe. But things are worse nearer to Oyster Creek and the road. About ten ditches have been cut from the railroad ditch on the east side of the track; but the same trouble is present here as on the other or west side, except that this ditch is mud-filled. The ditch on the side of the Oyster Creek road is in good working condition and sufficiently large to be used as an outlet for narrow drainage channels. Oyster Creek is also a good outlet and the problem is not a very complicated one; but it will require a good many ditches.

The territory between Oyster Creek and Sloping Creek has only a few breeding places which can be readily made safe.

Inspections showed that the area which is between Sloping Creek, Oyster Creek Road, the Central Railroad and Woodruff Creek has a number of bad places. But on this meadow the water soaks away so fast that not many mosquitoes find time to develop. Examinations were made several times soon after heavy rains and half grown larvæ were found in pools fast drying out while the majority were already dry and had a layer of dead wrigglers on the bottom. Oyster, Sloping and Woodruff Creeks can be used here for drainage outlets as well as the railroad ditch, which is in fair condition here.

The area south of Woodruff Creek, east of the Central Railroad to Newark Bay contains little that needs attention, the building of the Central Railroad repair shops having disposed of most of the bad breeding places.

The area between the Central Railroad, Great Island, Woodruff Creek and the Farmers road to Great Island is under water most of the time and there are a few very bad breeding places. But in most of the pools there is a good supply of fish which keep the larvæ down to a small number. The railroad ditch

here is all choked up, as it is further north, by the effects of the same high tide already mentioned and nothing can be done to drain this meadow until the railroad ditch is restored in proper shape.

On the south side of Woodruff Creek from the Farmers road to the Central Railroad there was a very bad breeding place. A few ditches were cut here by the city under direction of Mr. Richards and some of the holes were filled. This little work has greatly improved the territory involved and where millions of mosquitoes used to breed in times past, none can develop now.

On the north side of the Elizabeth River a very bad breeding place has been found. There are many holes and depressions in the low ground which hold water long enough to develop full broods of wrigglers. All of these can be drained into the Elizabeth River without much trouble.

On the area west of the New York and Long Branch Railroad to the highland and Elizabeth River, some very bad breeding places were found. It was here that some of the work done under the direction of Mr. Richards and referred to in his report was done. Ditches six inches wide and two feet deep were cut with the True ditching machine, and after this work was finished every breeding pool was dry and no breeding has been found at any time since the work was finished, though inspections have been frequent and always under conditions when the work done might be expected to break down—if at all. An incidental result of the work was an increase in both the quality and quantity of the hay crop on this meadow. A huge crop of the very best quality has been harvested without difficulty on territory which in times past was simply useless.

The area from the Arthur Kill, the New York and Long Branch Railroad east and west, and the Elizabeth River and the highland north and south, contained many breeding pools and, in 1903 was as bad as any place that has been discovered up to the present time. The matter was brought to the attention of Mr. Richards, who put in a gang to cut drains six inches wide and two feet deep. The entire area has now been cut up by ditches fifty feet apart and no further breeding can ever go on here provided the ditches are kept in order. They have stood and worked perfectly for two full seasons and the hay crop here has been fully equal in extent and value to that taken from the other drained meadow.

While the ditching was going on the pools were full of larvæ and, as the work could not be completed fast enough to prevent the change to the adult, oil was spread over the water and almost the entire brood annihilated. That was a case where its use was

imperatively indicated and where it paid for itself many times over.

The area from the New York and Long Branch Railroad west to the end of the meadow at Grove Street on the south side of the Elizabeth River has a number of breeding places where no ditching nor filling has yet been done. The meadow here is very narrow and could be easily drained into the Elizabeth River.

The stretch south of the Baltimore and Ohio Railroad to Morse's Creek and from Arthur Kill to the woodland contains a number of breeding places; but none directly on the marsh itself. The meadow is quite high, but the closer it gets to the mainland the lower it becomes. Water remains here a large portion of the time and breeding is almost continuous. This place will require a number of wide ditches into Morse's Creek and these must take the small laterals that actually carry off the surface water.

Morse's Creek is the southern boundary of Elizabeth.

It is interesting to note in this connection the importance of the railroad works on the meadow drainage problem. Apparently the companies have felt themselves free to build their embankments and tracks absolutely without any regard to the effect upon the surrounding land and their operations have resulted, on the Elizabeth meadow at least, in making matters much worse than they were before so far as mosquito breeding is concerned.

c. THE ARLINGTON PROBLEM.

Such breeding places as occur in Arlington are mostly in woodland, a large portion of the town being yet fairly well tree-covered. A very bad place is on the old Belleville Turnpike, just northwest of the old copper mine, made up partly of woodland pools and partly of fresh water swamp. It extends close to Kearny Avenue and is particularly virulent in spring: later inspections in July and August found every pool dry, and during these months two days was sufficient at all times to dry up even a heavy rain. In September the place fills again, and there is a small brood of fall mosquitoes.

A similar place is on the west side of the Rutherford Road, about 1000 feet north of the Belleville Turnpike, where there is heavy spring and light fall breeding, with a dry period during the summer months. The species bred in both these territories are the ordinary woodland species, chiefly *canadensis,* and they

are not especially troublesome except for *sylvestris,* which breeds here to some extent.

A very bad breeding place for *Anopheles* is in the cut through which the Greenwood Lake Branch of the Erie Railroad runs. Water trickles from the rocky sides at all times and forms a little stream or a series of pools along the sides of the road bed. There has been no real attempt to provide an escape for this water, which could be easily accomplished by a well-made drain.

A very large percentage of the house mosquitoes breed in the cesspools, Arlington having no sewer system.

The meadow just east of Arlington is not dangerous, except close to the highland or just at the foot of the hills, where some fresh-water species breed.

The area between Saw Mill and Kingsland Creeks is good meadow land, drained by large eight to ten-foot wide ditches, which extend from the highland to the creeks. There are sluices or tide gates at the mouth of each creek where it empties into the Hackensack River, so that the water may run out on the ebb and will not be able to get back on the flow. In this way what would otherwise be a dangerous breeding place is kept in good condition at all times.

Arlington, it will be noted, has no breeding places for salt marsh species, yet these form a large percentage of those that are troublesome during the summer. The local problem is a very simple one and chiefly concerned with the proper care of cesspools.

d. THE KEARNY PROBLEM.

The Kearny meadows are not so extensive as the Newark meadows and are not all salt marsh. Above Snake Hill the Hackensack River contains more fresh than salt water and that affects the character of the meadow. Eighty years ago that portion of it which lies north and west of the Pennsylvania Railroad was dense woodland, which was intentionally burned over and totally destroyed. The charred stumps and other tree remnants yet remain to show what existed in the past. At present the place is almost entirely grown up in cat-tails and other high grasses, which is not dangerous as a breeding area. Mr. Brehme made many inspections of this territory, but no larvæ were ever taken, except in a few pools near the Hackensack River opposite Snake Hill, and these were not of the salt marsh species.

South and east of the Pennsylvania Railroad line an altogether different condition of affairs is found. The area between the Pennsylvania Railroad, the Plank Road, the Hackensack and the

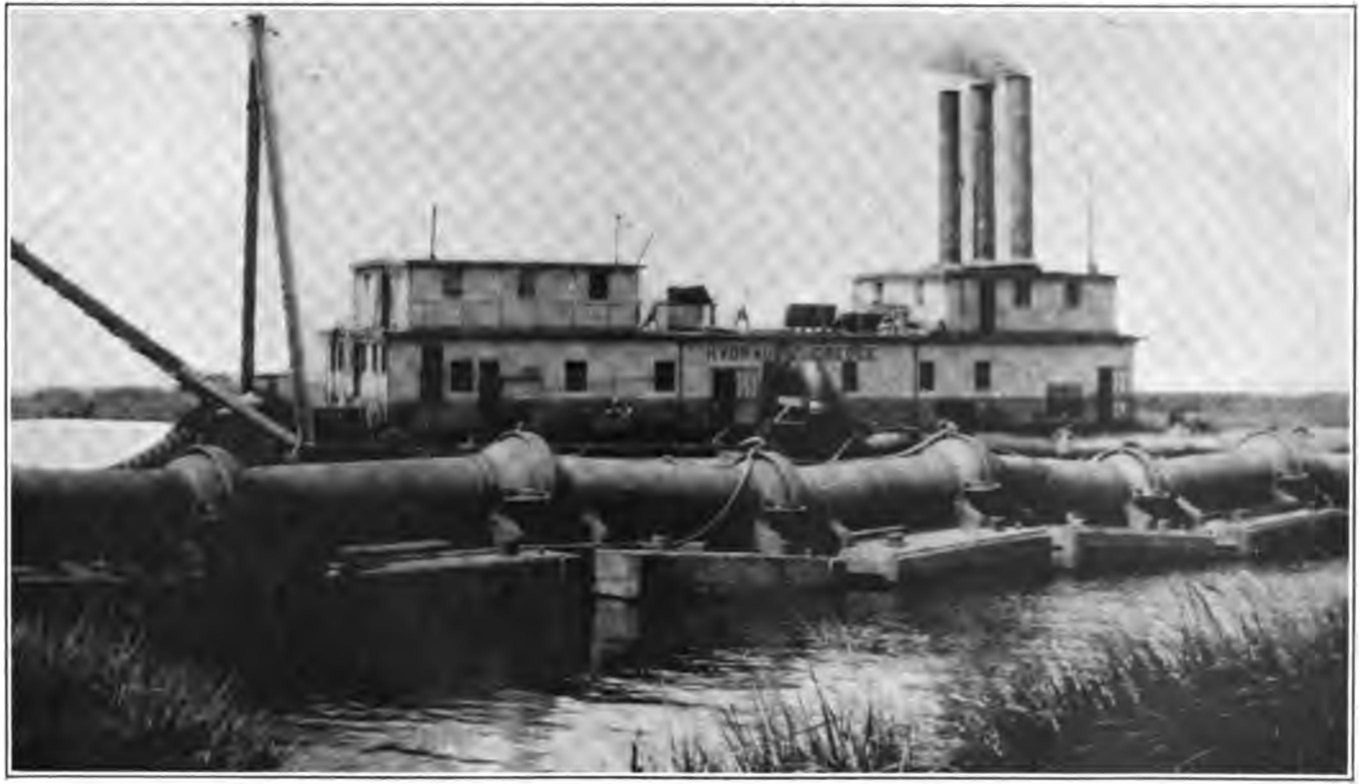

Figure 120.

The hydraulic dredge on the Passaic, filling in the Kearny meadows: shows the floats carrying the discharge pipe from the dredge to the marsh. (Original.)

Figure 121.

End of pipe line, discharging mixed mass of water and sand over the meadows: fills at the rate of three acres a day. (Original.)

Passaic Rivers is one of the worst breeding places in the State. Some years ago a company was formed to improve this piece of land. Wide ditches were cut and high embankments were made along the Hackensack and Passaic Rivers. This ditching operation would have been very satisfactory had they thought to provide an outlet for the ditches. Instead of that they ended blindly against the embankments; the water could not get out, nor could fishes get in. Only very extraordinary tides ever got over the embankment, and these, somehow, never brought fish, so there was nothing at all to prevent mosquito breeding on the most extensive scale.

No less than eight inspections of this territory have been made by Mr. Brehme, and in each case one or more of the ditches was followed for its full length. In every instance every ditch was swarming with larvæ and pupæ, and when a heavy storm formed pools on the surface of the marsh these also would be found filled with newly-hatched wrigglers. The days of this bad area are numbered, however. Two large hydraulic dredges are at present writing employed in pumping sand and gravel over these meadows and are covering acres in each day's work. The sand naturally slides along the line of the ditches first of all, and these breeding areas are becoming rapidly eliminated. As far as the water carries any load of sediment, the breeding has stopped even though more water than ever now covers the marsh surface. But toward the east, where the influence of the dredge is not yet felt, breeding proceeds merrily. It is certain, however, that if the work so well begun is continued through the summer of 1905, very little breeding area will remain; and, when this work is completed, Kearny will have practically no breeding places save such as are within the town itself and due to individual or municipal neglect.

The area south of the Plank Road to Point-no-Point, is entirely safe, first, because every tide covers most of it; second, because the cat-tails are so dense in most portions as to bar all mosquito breeding.

Though the dredging and filling now going on is not due to municipal enterprise and though the control of the mosquito pest formed no part of the plan of those who ordered the work, nevertheless the results from my standpoint are almost ideal and will prove an object lesson.

e. THE JERSEY CITY PROBLEM.

Under the general term Jersey City I include all the territory extending to Bayonne and the immediate surroundings, so far as

the direct mosquito supply is concerned. The investigation did not include the thickly settled area of the city itself, nor those lot pools and puddles on the immediate outskirts which can be readily dealt with by the Board of Health. These places furnish the local supply of house mosquitoes and the malaria carriers, which spread out a limited distance into the surroundings. Those clouds that sometimes make life miserable come from the marshes to the west of the city, and some of them from the Kearney meadows, which are now in process of reclamation.

The explorations began in April, 1903, when Mr. H. H. Brehme first went over the meadow, and have been continued from time to time by Mr. E. Brehme and Mr. Grossbeck, who covered the various sections under differing conditions.

The first area is on the north side of the Plank Road from the Hackensack River east to the highland and north to the old race track. This area has a lot of breeding pools scattered in all its parts; but there is no difficulty in draining them. Mr. Brehme reports: "We have here the Hackensack River and one good creek running right through the centre of this area from the highland to the river. Besides these two outlet streams there are a number of deep ditches. With all these natural and artificial outlets already present it will be easy work to lay the land dry and destroy the pools in which uncountable numbers of mosquitoes now breed."

From this territory every west wind carries mosquitoes into Jersey City and when it is a little south, Hoboken gets its share. On an east wind the flight is in the direction of Newark, and may add to the supply which the meadows in that city distribute.

The second section or area is south of the Plank Road from the river and bay to the highland. The meadow here is half a mile wide at its best and extends south about one and one-half miles. Beyond that, south to Bergen Point, all is sound and there are no breeding places. The Morris Canal runs through this piece of meadow land from the Hackensack River through to New York Bay. The little strip lying between the Plank Road and the canal is reported in pretty good condition.

That part of the meadow lying southwest from the canal is a bad breeding section, but here again, Mr. Brehme reports, we are supplied with outlet streams. The Hackensack is on the west side and there are a number of small natural creeks with a good tide flow, which can be used as outlets for drainage ditches.

The rest of this meadow was found in good condition to a point south of the Newark and New York Branch of the Central Railroad of New Jersey. Here is another small, but very bad

area, where mosquitoes breed in great numbers. The nearest point to which this can be drained is the Hackensack River, 400 feet away. It is a question whether turning it into a permanent salt pond would not be cheaper. From this point southward to the end the meadow is low, covered at ordinary high tides and every pool contains fish. Mosquito breeding under such conditions is impossible.

The third section is that area extending north and south from the race-track road to the Pennsylvania Railroad, and east and west from the Hackensack River to the highland. A bad place for breeding was found in the old race-track grounds. A creek wide and deep runs by this place less than 300 feet away, and this can be used as an outlet for drainage ditches—very little work really, is needed. On the west side of this creek is another little breeding area which can be easily treated by running a few ditches into the Hackensack River. North from the race-track breeding places may be found for a distance of about 1,000 feet and then comes a stretch of cat-tails and sedge in which no larvæ were found. This continues nearly to the line of the Pennsylvania Railroad, along which there are a number of bad places. All these places can be drained into a deep, good creek that runs into the Hackensack River. Very little work would be required to clean out this section.

The fourth section or area lies between the Pennsylvania Railroad and Penhorn Creek. Breeding places were found between the Pennsylvania and the D., L. and W. Railroads, but drainage here is easy, and only a few ditches directly into the Hackensack River are required. All the rest of the meadow land up to the County Road where it crosses Penhorn Creek is overgrown with cat-tails and other high grasses, but no more breeding places were found. There is plenty of water among these cat-tails, but practically no mosquito life. Three of the collectors have been over this area, not once, but several times under varying conditions and seasons, and while an occasional wriggler is found after hours of search, it is fair to say that this entire cat-tail area does not produce as many mosquitoes as a ten-foot breeding hole on the salt marsh would do. Furthermore, the larvæ found here are not of the salt marsh species, but seem to be *pipiens* or *restuans*. I have elsewhere emphasized the importance of recognizing these cat-tail marshes as safe areas, since it eliminates a very large stretch of what has been heretofore considered bad breeding territory.

The fifth section or area lies between the County Road and Paterson Avenue, and between Paterson Avenue and Granton.

The stretch between the County Road and Paterson Avenue is called Tyler Park, and in this are two islands or knolls, surrounded by a number of bad breeding places. To drain these, ditches must be cut through the cat-tails into Penhorn Creek. The remainder of the area is swampy and so densely overgrown with cat-tails that it is difficult to force a way through. No breeding places other than around the knolls were found. The stretch between Paterson Avenue and Granton is about three and one-half miles in length and about half a mile wide. Over this entire stretch not a mosquito larva was found except in the ditches along the New York, Susquehanna and Western and Northern Railroad of New Jersey Railroads. These ditches are fresh water and breed neither *sollicitans* nor *cantator;* the larvæ found there were *territans*, and it is probable that *Anopheles* will be found during the latter part of the season.

These are the larger areas that were explored and the fifth may be ignored as a source of supply to Jersey City. The fourth requires very little and is not a source of very heavy supply under ordinary conditions.

There are several other places, however, that do need attention though covering only a limited area. One is a small pond at Bergen Point, formed in a depression between three streets and a ridge of high ground. In this pond were great numbers of *Culex canadensis* and *Psorophora* larvæ and probably, late in the season, other species will breed there. Practically the only thing that can be done here is to use the place as a dump and fill it gradually.

Things were found to be pretty bad at Constable Hook. There were quite a number of breeding places and all the larvæ taken were *sollicitans*. This place can be readily drained into natural creeks, the Kill von Kull and New York Bay. Mr. Brehme comments: "At the time I inspected this area the pools were covered with full-grown larvæ and some pupæ. This place is near a thickly-settled part of the city of Bayonne, and the inhabitants must suffer greatly here. The work will be easy and it will require only a little amount of money to clean this pest hole."

Another place, belonging to Greenville, was found on the north side of the Morris Canal. This bred fresh water species only at the date of examination and is probably safe from the salt water forms at all times. It can be drained into the Morris Canal, but that is such a poor place to use for drainage that filling would be much more satisfactory.

Figure 122.
Hand ditching gang, Newark marsh: Mr. Brehme and Mr. Duryee in charge. (Original.)

Another breeding place was found out from the Bay View Cemetery, and the larvæ there collected were all *sollicitans.* There is a good creek here, and into this and the New York Bay ditches can be run, sufficient to rid the place of mosquitoes, for a very small outlay.

It should be noted in this connection that any place that will breed *sollicitans* will breed *cantator* also, and whichever happens to be the dominant salt marsh species for the time being is the one that will be found.

The last area examined lies between Claremont, Lafayette and Communipaw. In this territory there are lots of breeding places, but not of the salt marsh species. Most of the larvæ found there were *pipiens,* which were located very handily for getting into houses not far off. *Anopheles* also breeds in these places later in the season. In this vicinity cellar fumigation during the winter would produce excellent results and would throw back the appearance of the house pest toward the very end of the season.

It is possible to drain this territory into the Morris Canal, but filling is better, and the place is now actually used as a dump, so that its period of existence is probably limited.

f. THE NEWARK BAY PROBLEM AS A WHOLE.

Jersey City, Newark and Elizabeth, with the smaller cities and towns contiguous to or near by, make an aggregation of considerably more than half a million people. Millions of dollars are invested in manufacturing industries in the cities themselves and along the rivers and bays upon which they border. Many more millions are invested in suburbs like the Oranges, Montclair, along the Hackensack and Passaic Rivers and along the Palisades. And all these inhabitants in all these properties are every summer fighting and condemning the mosquitoes bred on the marshes described under the headings the Jersey City Problem, the Newark Problem, the Elizabeth Problem, and the Kearney Problem. Roughly speaking, they are the meadows that border the Newark Bay and extend up and between the Hackensack and Passaic Rivers to the point where the salt marsh changes to a cattail marsh where no migratory mosquitoes breed.

It has been made sufficiently clear that while there are many local points where mosquitoes breed inland, the bulk of the supply consists of the migratory forms.

It is the universal testimony that, but for the presence of the mosquitoes, property in most of the suburban places would

increase in value from 25 to 100 per cent. or more and that their population would increase by leaps and bounds. It has been demonstrated by this investigation that the solution of the mosquito problem means only the removal of the surface water from a comparatively small territory by the simplest ditching methods. The work done on the Newark meadows, where several hundreds of acres of breeding area were made safe, and that done on the Shrewsbury, where an equal area was almost completely rid of the pest, demonstrates this point. I am quite conscious of the partial failure of the work on the Newark meadow; but that was due to the intervention of the sewer problem, which simply required more work than was originally believed necessary.

As it stands this marsh area is of little or no value. Its potential value is indicated by the fact that a corporation has acquired a large section extending from the junction of the Hackensack and Passaic Rivers north to the Pennsylvania Railroad, and perhaps even further. Two powerful dredges are now at work pumping sand over this area and filling at the rate of acres per day. This territory only a year or two ago was the worst mosquito stretch between Newark and Jersey City. At present acres of these breeding holes have been wiped out completely and permanently, and if the work continues another year, this territory will be practically safe. It is, of course, expected that this land, so favorably situated, will be valuable for factory and other purposes; but there are acres of other marshes equally valuable for that purpose which owners would be ready to improve were it not for the mosquito pest which deters prospective builders.

The Newark Board of Trade has a Meadow Reclamation Committee which has worked for years under the able chairmanship of Mr. R. G. Salomon to secure the improvement of this marsh area within the Newark limits. They offered a $500 prize for the best plan for such reclamation, and awarded it to one that contemplated a primary expenditure of millions and a continuing expenditure of hundreds of thousands annually. To do this implies a recognition of the value these lands will have when reclaimed.

In view of the value of this land now good for nothing save to breed mosquitoes, and in view of the large population affected, it would seem as if there should be no hesitation by the municipalities concerned in taking steps to secure the preliminary drainage of the marsh lands, which will make life more bearable and would induce those who may wish to improve to do so.

The city of Newark has done its share of the work; not quite so completely as was intended, but it will not stop until it is done.

The city of Elizabeth has done some work, and efforts are being made to have the entire breding area drained.

Jersey City has done nothing and has not even manifested the slightest interest in the work, though it suffers at least as much as any.

The Kearny problem is by way of being abated as already stated.

All this territory must be cleaned out before any of the cities realize fully on their investment, because these marsh species travel so far. Nevertheless Newark will have fewer mosquitoes than ever before in 1905, and the improvement will be even more realized in the outlying territories which derived their main supply from the Newark Marsh.

CHAPTER II.

CAPE MAY COUNTY.

a. THE WORK AT CAPE MAY.

For a number of reasons Cape May was selected as the point for making studies on the life history of the marsh mosquitoes, and Mr. Viereck was stationed there, with instructions to spend what time was available in considering also the practical side of the question. His reports were so unexpectedly favorable that, after looking over the ground myself, I assigned Messrs. Wagner and Mellor to make a somewhat more detailed survey. The reports made by these gentlemen speak for themselves and show a condition more favorable for mosquito control than exists anywhere along the South Jersey shore. In fact, a more ideal position for a summer resort of the best class can scarcely be imagined. Starting at the west is the highland at Cape May Point, where no mosquitoes breed, and this gradually merges into the marsh at South Cape May. This marsh is the largest single problem, yet not difficult to deal with. Along the line of the trolley and on both sides of it, extending into Cape May City, are pools in which the wrigglers are found by the million. In West Cape May and in other parts of Cape May City, just north of the more densely built up sections, there are depressions in which pools form after heavy rains. All these can be easily brought up to grade or drained. Toward Sewell's Point an extensive marsh

area begins just back from the series of sand hills fringing the shore, continues along the highland at Schellinger's Landing and beyond toward the Two-mile Beach. The marsh is now being filled in by the Cape May Realty Company and its days as a mosquito breeder are numbered. To the east, south and west the influx of mosquitoes is prohibited by the sea and bay; from the north nothing can come from points beyond the Cape May limits. Only from the northeast at Two-Mile Beach can any migration come and northeast winds mild enough to favor mosquito flights are rare in summer. In a single year at a very moderate cost, Cape May can be made mosquito proof. Since the following reports were written, the railroad companies have improved the conditions along the trolley line, but the municipalities at present writing have done nothing, though all the facts have been submitted to them.

Practical Results of Mr. Viereck's Investigation at Cape May.

Cape May, Cape May Point, South, West and *East Cape May* receive their largest supply of mosquitoes from local breeding places. During the day *sollicitans* was always dominant; in the evenings *Anopheles crucians* and *Culex salinarius* or *pungens* or both were the chief nuisances. In the favorite day retreats, viz., the salt hay, mosquitoes were scarce when the wind was from the south, with the grass moist; more numerous when the wind came from the north, causing the grass to become dry, and most numerous during calm weather, particularly after a brood had emerged, if no strong winds intervened.

The observations at Cape May were begun May 26th and concluded September 30th; in the beginning *sollicitans* alone was numerous, but after June 26th *Anopheles crucians* and *Culex salinarius* came in great numbers, *Culex tæniorhynchus* and *sylvestris* next in importance; *C. perturbans* appeared periodically in small numbers.

The features that have to do with the problem are best taken consecutively from Cape May Point to Sewell's Point. Starting on the bay shore, for some distance up is highland down to the bay; at Town Bank very high. The suspicious area is the marsh drained by Pond Creek and of considerable extent. The natural drainage of Pond Creek marsh has never been permanently interfered with, so the marsh has a chance to drain and fill with the falling and rising of the tide. For a short distance on the north and south sides of the marsh the edge thereof was explored; on the north side all suspicious spots were full of salt water and

Figure 123.

The hydraulic dredge at New Cape May in winter: shows the line of discharge pipe, 30 inches in diameter, extending across the marsh. (Original.)

stocked with killies; on the south side no serious breeding, but good slopes were found; only in a sheltered cove, a fresh water swamp, were larvæ found, and these were scarce and belonged to *Anopheles*.

Cape May Point is largely safe highland, its breeding places exclusive of the share it has in the Cape Marsh, are limited to depressed city lots from Lake Lily to near the beach directly south. Lake Lily is stocked with fishes, deep, and practically free from *Anopheles* harbors along the edges; hence free and safe. The lake north of the lighthouse is rather choked up, has edges rank with cat-tails and breeds *Anopheles* there. The city lots should be graded, because a satisfactory drainage system appears to be impossible on account of the condition of the Cape Marsh. The only remedy for the lake north of the lighthouse is a drainage system subsequent to the draining of the Cape Marsh. The remaining breeding places for Cape May Point are the salt hay depressions between the railroad and the beach dunes east of the Life Saving Station, which can readily be graded, and part of the Cape Marsh, the greatest part of which belongs to South Cape May.

South Cape May shares with Cape May Point the Cape Marsh, the area which is responsible for the great numbers of *Anopheles crucians* and *Culex salinarius*. The Cape Marsh extends from Cape Island Creek to the bar forming the beach, and from the vicinity of the light house to Cape May City; the dangerous part however lies between Cape May Point and Seventh Avenue, South Cape May. The Cape Marsh was drained at one time by two creeks, one emptying directly into the ocean in South Cape May and this has been obliterated by storms, i. e., closed up; the other and remaining outlet is Lower Cape Island Creek which empties into the ocean at Cold Spring Inlet. The remaining creek is insufficient, consequently the marsh has become congested, cat-tails, sedge and salt hay, matted so as to keep out fishes and standing in water from a few inches to over a foot the greater part of this season. The marsh is the breeder of the permanent water mosquitoes or the species that lay their eggs on the water. Until this marsh is drained, summer evenings in Cape May and neighboring boroughs will be uncomfortable. South Cape May has taken up the matter and is about to build a tide gate, the first step in the solution of the Cape Marsh problem. Once the tide gate which is to be built near Seventh Avenue is in operation, it will be easy to see just what amount of ditching must be done to complete the cure. This tide gate should be supplemented by a second under Broadway bridge in Cape May. One other danger area exists; it is the depressed

creeks may be drained by ditches, if the soil does not prove too sandy.

Poverty Beach, now controlled by the Cape May Improvement Company, is the last danger spot toward Sewell's Point and Two-Mile Beach. One-half of the breeding area, the chronic portion, was made harmless by the construction of ditches to admit the tidal water, so that the breeding was materially decreased. The remaining area, that near the Cold Spring Life Saving Station, will become obliterated in the course of the filling-in operations of the Improvement Company; this filling-in to take place this winter. Mr. Cloud, who was the proprietor of the Sewell's Point House during the summer, was very much troubled by the mosquitoes before the ditching. He confessed they were quite satisfied that the numbers were so materially diminished that they could readily cope with the small number that appeared since from other sources; this is simply a corroboration of the utility of local action.

Two-Mile Beach is so near to Cape May that it needs attention in the solution of the mosquito problem of Cape May. Only the lower half, i. e., the southern, is capable of breeding mosquitoes. Here there is a zone of salt hay between the sedge and highland in which there are some serious and other less important depressions, all of which could be drained through ditches into the nearby thoroughfares or creeks.

Extras. Out at the canning factory on the Pennsylvania Railroad is one of the worst breeders of the salt marsh species near Cape May. It can be ditched quite readily.

Along the country roads depressions were found breeding mosquitoes—all are marked on the map. One over the bridge from Schellinger's Landing turned out *sollicitans and tænio-rhynchus.*

Along the edge of the highland from Cape May to Anglesea Junction danger spots were found wherever a depression occurred in the salt hay, still the breeding was in no place so heavy as in the chronic pools in Cape May City.

Wagner and Mellor's Report on Cape May.

(1) Along the Cape May beach are two trolley lines. On either side of the inner one, for the distance extending from Seventh Avenue to where the two lines meet are bad pools. These occur in sandy ground and nothing can be done except to fill them.

(2) Between the Villa Nova and Seventh Avenue are three pools, designated the Villa Nova pools. When it rains, they collect water and become breeders. They should be filled.

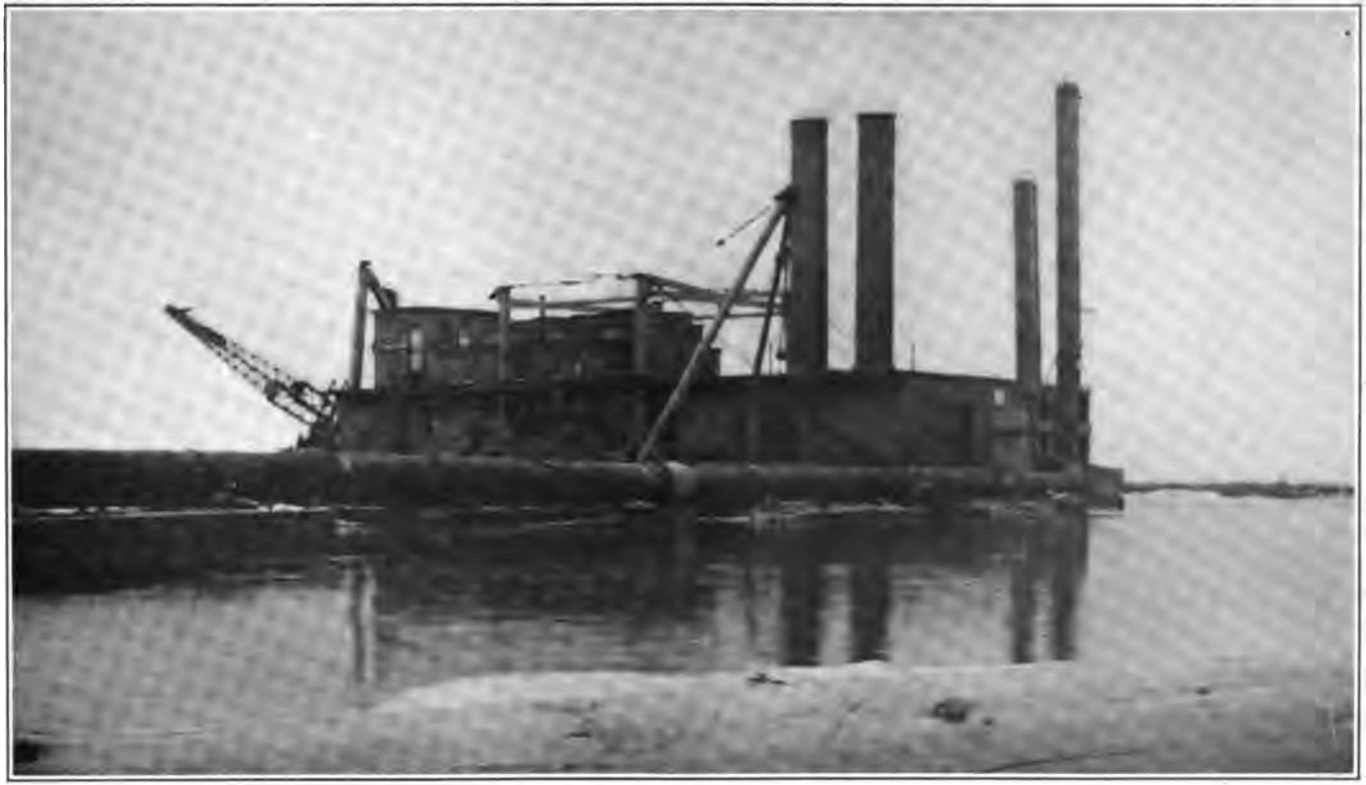

Figure 124.

The hydraulic dredge at New Cape May. Near view, showing the floats that carry the discharge pipe to the marsh. (Original.)

(3) About 200 feet west of the Villa Nova, and lying between it and the inner railroad, is a large pond. It has no outlet. We found no larvæ there, but if hot weather should dry it, ensuing rains would make it a breeder. It has been known to be perfectly dry, and so to be safe a ditch should be led from it under the railroad straight to the creek.

(4) At the Florida Cottage on Broadway are two bad depressions. One is in the lot south of the cottage; the other is in the adjoining lot north of the cottage. They are comparatively dry usually, but after rains they breed profusely. They should be filled.

(5) On the east side of Broadway, directly opposite the power house, there is a pool which breeds plentifully. This pool has probably been caused by the building of the railroad right near it, which has cut off the flow of water to the creek. A short ditch led under the railroad and emptying in the creek will drain the pool.

(6) On the north side of the turnpike, extending an average of 300 feet north, the land is wet from Broadway to Seventh Avenue. But the water is led under the street into the creek and rises and falls with the tide. So the territory is mainly safe. At Eighth Avenue, however, there is a bad spot. There is a pipe here under the road to lead off the water, but the land on the south side of the turnpike is four inches higher than the land on the north side, so the water cannot get off. A ditch should be dug directly south to the creek. This will give the water a fall and take it away.

The Cape Marsh.

(1) Extent and Character. The marsh extends west from Broadway to within 1200 feet of the lighthouse. It extends north from the inner trolley road. East of Seventh Avenue it extends north to the turnpike. West of this Seventh Avenue it does not reach to the turnpike, preserving a fairly uniform width until its most western point.

The marsh is covered with grassy growth, very congested in parts. The extreme prevalence of strong grass makes it hard to dig in, but it will very well maintain a ditch.

(2) The Cape Island Creek. The creek extends to Seventh Avenue. About ten years ago a ditch four feet wide was dug from here through the marsh to its westerly extremity, thus making this ditch a part of the creek. The ditch was intended for haying purposes. Up to 900 feet west of Ninth Avenue the stream has a good flow. The difference between high and low

water is 1.9 feet. The difference between high and low water in the ocean is about four feet. The variation between the stream and the ocean is due to this: The stream is so narrow that before the water of high tide has all run off, tide changes again, backs up into the stream, and so the fall of water is not great. West of 900 feet west of Ninth Avenue the stream is poor. In some places a little water oozes through; in others vegetation has completely choked up the stream. The reason of its having become choked is this: A stream, to be free, must have a fairly good flow, or else a tide-gate to lower the level of water and prevent it from standing still. The ditch has very little natural fall, and besides, the tide-gate (half way between Second Avenue and Seventh Avenue) has been in a useless condition for a long time. The result is that the ditch has become clogged. When it was first dug it drained the whole swamp. Now it does not drain at all.

(3) Extent of Breeding Area.

Between Broadway and Seventh Avenue no breeding goes on. Water rises over the land, but recedes with the ebb of the tide.

Between Seventh Avenue and Ninth Avenue the grass growth is very thick. High tide gets up here, fish are kept out by the density of the vegetation and breeding goes on. This is true of the land on the north side of the creek for 900 feet west of Ninth Avenue.

In that part of the swamp where the ditch has ceased to drain, rains have collected and the ground is submerged, breeding going on. Added to this is the backing up of water due to the poor condition of the tide-gate. In the western end of the marsh affairs are especially bad, there being two feet of water, and the original ditch is hardly distinguishable.

(4) What Should Be Done. Since breeding areas have resulted from the degeneration of the ditch, evidently the thing to do is to clean out the ditch. Originally it drained the marsh. If cleaned, it can do so now, since no point of the marsh is lower than the ditch. In conjunction with the fixing of the ditch, a good tide-gate should be put in. This will lower the level of the water and will keep high tides from backing into the marsh.

(5.) It may be that when the marsh is drained, there will remain separate depressions that will need ditching. Data for this purpose, however, cannot be determined until the ditch is fixed and the tide-gate put in. The immediate problem is to clear the marsh of the surface water that is now on it.

b. MR. VIERECK'S WORK.

Beginning in the latter part of May, 1903, Mr. Henry L. Viereck carried a series of observations and experiments at and near Cape May City, which lasted until the end of September. Excursions were made to several other shore points and from time to time he was sent for a day or two on special service, but on the whole the Cape situation was kept under a continuous observation. The main object in view was a close watch on the banded salt marsh mosquito *Culex sollicitans,* to determine its habits, the normal place and manner of laying eggs, the reasons for migrations and the circumstances under which they occurred. Next in view was an exploration of the surrounding territory to locate breeding places and to determine the possibility of practical control.

Aside from these main lines instructions were, in general, to keep a watch on all mosquitoes found, to make collections of all stages, to watch their habits, to determine their natural enemies and other checks and also the circumstances which favored their development.

A line of experiments with fish gave results which are elsewhere detailed, and a series of experiments with its eggs gave us an explanation for the peculiar breeding habits of *C. sollicitans.*

May 25th, mosquitoes were already plentiful, and a brood of babies was in the pools, which, however, were drying up. In all the live ditches fish were found and in many of the higher pools there were young, half an inch long, which were not able in all circumstances to keep down the wrigglers because of dense vegetation, which made it impossible to get about very much. Up to June 3d general explorations were made and areas suitable for experiments were located. June 4th experiments were begun with the common " killies," *Cyprinodon* and *Fundulus.* June 8th, mosquitoes of the second brood began to appear and some experiments were made with oils to determine their relative value as larvicides. Explorations had been extended meanwhile from Sewell's Point to Cape May Point, through the Cape Marsh and to Two-Mile Beach, at which place a heavy brood of adults was just developing. June 12th, the Five-Mile Beach territory was investigated and a new or third brood was found fairly under way. June 16-20th was spent along Seven-Mile Beach, where the situation is more complicated than at any of the points further south, but a fairly good idea of the dangerous breeding areas was obtained. June 22d, the third brood was fully started

at Cape May, and at that time Mr. Viereck began a record of the vegetation found on the areas where breeding is most active. Explorations were also carried further inland and breeding places for *Anopheles* and the fresh-water *Culex* were located.

As it was a matter of decided importance to determine whether *C. sollicitans* bred in the marshy lowlands along the railroads and at the edge of the highland, the whole stretch from Cold Spring to Anglesea Junction was carefully collected over, with the result that not a larva of this species was found. This is a vital matter to Cape May, because with a safe highland at the point and on the bay shore, if the north or land side be not dangerous, the problem of cleaning out the narrow shore strip between Cape May Point and Sewell's Point becomes a very simple engineering problem. Adults of *sollicitans* are horribly abundant all summer everywhere in the territory just mentioned, and Mr. Viereck's absolute failure to find larvæ so near the coast, confirms my conclusions from observations made further inland.

June 26th, I covered part of the territory with Mr. Viereck and was surprised to find *Anopheles crucians* the common species of that genus. The species had been rarely found, elsewhere in the State, and its early stages were yet unknown; therefore Mr. Viereck was directed to work out its life cycle.

June 27th, egg-filled females of *sollicitans* were numerous and everything bid fair for a new brood. At about that time a very high tide covered the pool areas and left "killies" everywhere. But adults enough had emerged to make life interesting and early in July the proprietor of the house at Sewell's Point "swept mosquitoes out of a room where they had collected during the night to a depth of nearly an inch."

July 7th, half-grown larvæ were found at Two-Mile Beach, but none at Cape May, where mosquitoes decreased in number, leaving only gravid females in the damp places where larvæ would be expected should they fill up later.

July 11th, Mr. Shields, of the Cape May Real Estate and Improvement Company, went over the mosquito-breeding areas on Poverty Beach with Mr. Viereck and agreed to ditch and drain them. Mr. Viereck had been instructed to offer every possible help to any individual or body that showed any disposition to do active work, and he did not only give such help when asked for, but interested a number of local people in his work.

July 13th, came a heavy northwest rain, filling all pools, and July 14th, recently-hatched larvæ of the fourth brood were abundant everywhere. The search for *sollicitans* larvæ along the highland was rewarded by finding a few of them in a pool at the corner of a corn field where it joined the marsh.

Figure 125.

The pool on Cape May, in which 10,636,704 mosquito larvæ developed at one time; the sixth brood of the season. (Original.)

July 15th, the search was continued further inland; but in three fresh water swamps not a larva was found, while in the salt hay zone every pool was full of them. The area between Bennett's and the marsh was especially explored, and the relation between the presence of certain grasses and *sollicitans* breeding grounds was fully investigated. The thorough exploration of this area was of the utmost importance because it left no question as to the limitations of *sollicitans* breeding areas, and no room for further dread of the fresh water swamps as mosquito purveyors.

July 16, experiments with killies were continued and several pools near Cape May were stocked with them. The fourth brood was now in full swing and the fish had an excellent opportunity for showing what they could do. The details of these experiments are elsewhere given.

July 17th and 18th were spent in continuing the fish experiments and in watching the race between developing larvæ and drying pools—millions of wrigglers dying because the water evaporated forty-eight hours too early.

July 19th mosquitoes were found in immense numbers near Hammonton and at Da Costa, in the grass and bushes. Most of them were *sollicitans;* but there was a fair sprinkling of *cantator;* all of them were females without eggs. Not a wriggler was found in the swamp pools where these adults occurred by the thousands.

July 19th and 20th some of the fish experiments were brought to a conclusion, the larvæ were found ready for the change to the pupal condition and some adults from this fourth larval brood were already on the wing. It was noted that the *Anopheles crucians* and *Culex salinarius* were the house mosquitoes, while *sollicitans* rarely got into the rooms.

July 22d adults were emerging in swarms from what Mr. Viereck called the July 13th brood of larvæ; and now *Culex tæniorhynchus* began to be quite common. On the 23d, similar conditions were noted near and at Anglesea, and collections were made everywhere to determine the relation of the two species.

An elaborate series of experiments was begun at this time and continued through the balance of the season, to learn the conditions under which the adults will lay eggs and the circumstances under which they will hatch. Mosquitoes became very plentiful at Cape May during these last days of July, but *Anopheles crucians,* whose breeding place had now been located, and *Culex salinarius,* were still the dominating indoor forms. Every day some new locality was explored or some question of habit was determined.

August 3d a flying trip to Ocean City located some of the principal breeding areas and at Atlantic City it was observed that *C. pungens* seemed to be the most troublesome form at night.

It was noted that the continuous south winds resulted in a lessening of the numbers of fresh mosquitoes and it was further found that *sollicitans* would bite readily enough after the eggs were all laid, if a chance was offered. Practically all the gravid females found at this time had remnants of blood food in the alimentary canal, and Mr. Viereck rather concluded that most of these were return migrants that had been inland to feed and came back to the marshes to deposit the maturing eggs.

August 6th, Mr. Seal joined Mr. Viereck in a systematic collection of the small fish found in the tide pools, ditches and channels, the object being to determine whether the top minnow, Gambusia, occurred anywhere in these waters. This little fish is the most effective enemy of the species of *Anopheles*, but unfortunately no signs of it were found.

Ditching to drain the mosquito breeding pools on Poverty Beach was begun at about this time, and Mr. Viereck assisted by pointing out the dangerous places and in a manner superintending the work.

August 7th the marriage flight of *salinarius* was observed early in the evening and described, and on the 8th the advance guard of the fifth brood of *sollicitans* was noticed. August 9th it rained, and on the 10th there was a lively wriggler population in nearly all the new pools. Where fish had been introduced and had survived, they apparently disposed of the larvæ as fast as they appeared, and so more of the larger pools on Poverty Beach were stocked while the ditching work was carried on. It was also found that in places where the salt hay had been burnt, the pools contained no wrigglers; so the question arose whether the fire had destroyed the eggs or whether none had been deposited in the charred surface. On the 12th, *A. crucians* was bred, and its larva positively determined. Experiments were also made with some predatory beetle larvæ, which occurred in pools tolerably free from mosquito larvæ and one specimen ate or killed 434 wrigglers in less than three days!

Another dry spell coming on, pools disappeared rapidly, leaving the surface covered with dead wrigglers and over these areas *sollicitans* and *tæniorhynchus* were observed in numbers. In a few pools the mud was yet moist when, on the 19th, a shower partly refilled them and gave new life to a few larvæ that had been buried for at least twenty-four hours. They seemed none the worse for their experience and pupated normally. A shower on the 20th filled up some salt hay pools on Poverty Beach burnt

over area, but no larvæ were found in them on the 21st. At dusk the marriage flight of *salinarius* or *pipiens* was again observed and *perturbans* was added to the list of species found. Intense heat and bright sunshine dried up pool after pool and in those stocked with fish only a few were left floundering in the mud of the deepest holes.

A very heavy rain on the night of August 25th filled every depression and started brood six—the heaviest of the season. On the 26th, young larvæ were everywhere and the breeding areas were again explored to determine differences, if any. For the first time larvæ of *Uranotænia* were found in the Cape Marsh. Another heavy rain on the 28th followed by a storm on the 30th, gave the greatest precipitation of the season and life to every possible breeding area. The adults of the fifth brood were about gone and except for *pungens, salinarius* and *crucians* in the houses, Cape May was almost mosquito free for the time being. Again the inland and highland pools were collected over and larvæ of *sylvestris* were now common; but no *sollicitans*. *Psorophora* and *sylvestris* were found together at one place.

September 1st, *Anopheles crucians* was found breeding along the marsh in South Cape May, and this species was now a great nuisance, biting even during the day. So dense were the wrigglers in some of the pools that Mr. Viereck determined to fix their number at least approximately. Selecting a pond with an area of 1,894 square feet, he dipped at numerous points with a dipper of known surface, and counted the larvæ in each dip. These counts were averaged and, calculating from this, the pool contained 10,636,704 wrigglers—roughly ten and one-half million—or 5,616 to every foot of area!

September 3d, a sphagnum swamp near Sea Isle Junction was carefully collected over because *sollicitans* abounded there earlier; but not even a sign of a larva was found. Between Seaville and Swain *Anopheles crucians* and *Culex pipiens* larvæ occurred in the ditches except over sphagnum ground, and no larvæ were found in the sphagnum swamps. Conditions on the marshes favored development, so that at this date the larvæ were pupating generally and some adults had already emerged. Again the marriage flight of *nigritulus* was noted, but this time at a height of twenty-three feet, whereas the previous flights had been from six to ten feet up.

September 4th, adults of *sollicitans* and *tæniorhynchus* emerged in force, and the ditched area on Poverty Beach was explored. Not a larva was found anywhere and scarcely an adult in the grass where earlier in the season they swarmed. The work done had been entirely effective. On the 11th the proprietor of the house

at Sewell's Point, who had in early July swept mosquitoes out of his rooms by the thousands, reported that since the ditching was completed they had had very little trouble.

September 9th, adults were very numerous, but no gravid females were seen and explorations were carried along the pike to Bennett's Station. *Sylvestris* now began to come to the porches, but in small numbers. Collections and notes were made until the 16th, when a terrific gale with rain following supplied fresh water to all breeding places. On the 17th brood 7 was found in the pools in small numbers, and from the facts reported it seems likely, though Mr. Viereck does not say so, that these were left-over eggs from the sixth brood. In the evening, gravid females of *sollicitans, salinarius, tæniorhynchus* and *crucians* were taken around the electric light. By the 18th the larvæ had been eaten up in the fish-stocked pools, even where only a few had survived the drought. A new brood of *Anopheles crucians* had started September 19th in the Cape Marsh.

September 24th, Lake Lily at Cape May Point was again examined and found free from mosquito breding areas. Several times during the summer this lake had been carefully looked over and on each occasion the record was the same. It might not be safe to say that absolutely no mosquitoes developed in it during the year; but the water is well stocked with fish, and aquatic insects are present in great abundance, so that only in a few grassy shallows is breeding possible. The salt marsh species simply cannot live there at all. At this fag end of the summer mosquitoes were very abundant and *crucians,* unlike the others of its genus, was troublesome even during the day.

The larvæ of brood 8 were found in pools on September 28th and 30th, and this ended the work of the season for Mr. Viereck. Egg-laying was very active at that time, gravid females being plentiful; yet most of them with only a very partial supply of eggs, indicating that oviposition had been in progress for some time. The majority of these ova were probably the provision for a 1904 supply.

The practical value of the work done by Mr. Viereck can scarcely be overestimated, and elsewhere in this Report will be found more detailed records of his observations and conclusions. Not the least interesting of these are on certain parasites and predatory forms which materially lessen the numbers of mosquitoes at certain periods.

c. TWO-MILE AND FIVE-MILE BEACH.

Two-Mile Beach is uninhabited except for the crew of the life-saving station and it has no direct connection with the mainland. Access to it is by boat from Sewell's Point or Holly Beach, and it is a mere ridge of sand, with more or less of the usual shore shrubbery. Mr. Viereck covered this territory for the first time June 10th, "by boat from Schellinger's Landing, through lower Cape Island Creek, Cedar Island Creek, Cape Island Sound, through a thoroughfare, Jarvis Sound, another thoroughfare and Swans Channel; walked from the upper end [north] of the island to the lower end. The mosquito area is a zone of salt hay, which extends from about one-fourth mile above [north of] the life-saving station to near the end of the beach or island. It is a strip about one hundred to two hundred yards wide, with pools and holes and areas of sedge under water; no fiddler crabs and no fish. The worst part is above and opposite the life-saving station and all lies between the highland and the sedge marsh. Below [southwest of] the life-saving station the salt hay meadow is more entire, but there are some puddles with larvæ in them. The adults were rapidly emerging and were present in great numbers in the grass at the edges of the pools. The largest mosquito pond is opposite the life-saving station."

July 7th, the same ground was again covered, and it was found that the largest breeders had been neutralized by the high tide which covered them and left fishes behind. All the specimens found were *sollicitans*.

Two-Mile Beach in itself is of little importance, the only persons directly affected being the life-saving crew, which is about as nearly mosquito proof as any individuals may hope to be. But in a direct line the breeding places are only a mile or two east northeast from New Cape May, and while this is not a prevailing wind in summer nor one on which mosquitoes usually fly, yet a quiet warm night with a gentle southwest wind may tempt the insects to fly against it. From Wildwood and Holly Beach they are further removed, but a southwest wind which is quite a common one, will readily carry the swarms over the four or five intervening miles. For their own protection these communities must see to the clearing of Two-Mile Beach and fortunately this is an easy task because the island is narrow, there are plenty of little inlets to receive ditches and there is sand enough readily available to do what little filling is needed. It is a matter of a few hundred dollars only and a few weeks' work for a small gang.

Five-Mile Beach has taken an enormous start during the two or three years last past, and many thousands of dollars have been spent in permanent improvements, principally at Wildwood and closely adjacent to it in Anglesea. I have known Anglesea and its surroundings for fifteen years, and when I began my investigations into the habits of the marsh mosquitoes I naturally selected Anglesea as the proper place, because nowhere have I known them to be more abundant or blood-thirsty. Like others, I believed the broad marshes to be in fault and was fully convinced that extermination or even practical control was an iridescent dream. But when, after several days on the marshes with Captain Ben. Hankins, I found these square miles of marsh land safe, while at the edges of the highlands only were conditions favorable for breeding, I began to think hard and to believe that after all there might be a practical side to the matter. I have tramped over or rowed round almost every island from Shell-Beach Landing to Jenkins' Sound, extending due east to the life-saving station on the shore, southward to Turtle Gut, Swan Channel and Jarvis Sound, touching there the limits of Mr. Viereck's work from the south. In all that stretch of marsh there are not bred, under ordinary conditions, as many mosquitoes as develop within the limits of Anglesea itself.

Five-Mile Beach was within the scope of Mr. Viereck's explorations, and his first visit was on May 12th, 1903, when there were plenty of adults but no larvæ anywhere. A month later conditions had changed, and larvæ occurred everywhere along the edge of the highland. This highland is a back-bone well wooded with conifers and deciduous trees, large holly trees forming a characteristic feature toward the southern end. There are ponds and fresh water swamp areas of considerable extent with a very rich flora and insect fauna. Between this highland and the sea there are sand fields and hills, shifting and varying from year to year, in which little or no breeding goes on until Holly Beach is reached. Here the marsh area curves round the edge of the high ridge and there are breeding places everywhere—even in streets where these become covered by tides or flooded by rains I have been at Holly Beach frequently during 1903 and 1904, and at no time did I fail to find larvæ near the beach or bay termination of almost every street. Most of the streets are of sand, badly cut up by wagon ruts, and whenever these hold water, there are wrigglers. In the marsh areas cattle have been fed and in almost every hoof print larvæ are to be found. For Holly Beach the first necessity is to get the streets in good shape and the depressions on the shore side filled. Ditching is impossible because

there is no turf to hold a ditch. Filling material is quite plentiful in the sand hills, so there need be no trouble on that score. On the land side there are no very serious breeding areas and none that cannot be readily drained. In Wildwood the streets have been recently improved and many of them continued from bay to the shore. Those that have been newly made are faced with gravel and so far as the public highway is concerned there is not a single breeding area within town limits. But some of the areas between the streets lie lower than them, and in some of these areas water may lodge long enough to mature a mosquito brood. It is easy in most cases to fill these danger spots and in some places that is being done. On the marsh side of the elevated ridge things are not so favorable and there are yet many breeding places, but they are usually small and can be readily drained or filled.

Anglesea occupies the northeastern end of the island and is at present a sufferer from the sea which has cut off heavy slices at the mouth of Hereford Inlet for the several years last past. In a few places the sand hills between the highland and the shore have formed depressions which hold water and some of these, with a coating of vegetation, are mosquito breeders. But the location of such pools shifts from year to year, and it is not easy to determine just where conditions will favor breeding. There is one point, however, in all cases: Wherever such a depression exists the material to fill it is equally at hand and a few days' work early in the season by an intelligent man will prevent all trouble later. Here the highland tapers off into the marsh, but conditions are not nearly so bad as they are at Holly Beach within town limits. Nevertheless just beyond the railroad station and on both sides of the road leading from the Hotel Germantown to the creek there is an area that supplies the entire town and leaves a surplus to spread over the marshes. On the marsh side of the highland its outline is irregular, and many cuts and indentations extend inward for a longer or shorter distance. Almost all of these are breeding places and there are some breeding places between the old and new railroad line where natural drainage has been interfered with. Ditch drainage is quite possible for most of this area, though in some places, at the edge of the highland, filling will be cheaper and more advantageous. In a few places the wagon roads across the marshes have cut up the surface so that pools form in which thousands of specimens breed. Filling these depressions with marsh grass or sedge will stop the breeding and improve the road.

Taking Five-Mile Beach as a whole, there is nothing to prevent clearing the island by the simplest ditching and filling operations. There are some wide shallow ditches now, in some places, that have been allowed to become choked with grass and rushes. There is probably not a square foot of mud bottom or low sod on the island that does not have its complement of mosquito eggs. Wherever water lodges over these wrigglers will develop, though without doubt most of them perish because the water does not remain long enough to allow them to come to maturity. I doubt whether any considerable number of specimens reach the beach from the mainland. I am much more ready to believe that there is a migration the other way. The only real danger of incoming swarms is at Two-Mile Beach, though at times the lower end of Seven-Mile Beach may send in a supply.

The work of general improvement which is now under way is all good and tends toward lessening the number of breeding places. But it might pay to leave some of the outlying streets unfinished and apply the money and work to abate the mosquito pest. The fresh water swamps in the centre of the island may be ignored at present.

The highland has been several times referred to and its conditions were studied by Mr. Viereck from Cape May to Burleigh. All along the edge there is the usual breeding area before the flat marsh begins, but no very bad places were found, and there is excellent natural drainage, which needs only a little intelligent extension to reach all danger points. The fresh water and sphagnum moss swamp areas breed none of the dominant mosquitoes. This narrow strip at the edge of the mainland in all probability supplies the interior of the peninsula, reinforcing the larger swarms which come from Cape May, more directly south.

d. SEVEN-MILE BEACH.

This has Avalon at its northern end, Peermont less than a mile south, and Stone Harbor a little south of the center. This latter place is the terminal point of the railroad which extends from Ocean City about twenty miles to the northeast. Southwest of Stone Harbor is a stretch of three miles on which Life Saving Station No. 35 is the only inhabited point.

Mr. Viereck writes concerning this stretch as follows: "Seven-Mile Beach is widest between Avalon and Peermont and for some distance south of Peermont. It is this part of the island which is more complicated than any place yet visited. The cardinal physical features are, from the beach inward, depressions

in the grass grown sand near high water line; then the sand dunes with either meadow land or fresh water swamp between them and the wooded strip, then the salt hay zone, beyond which is the sedge marsh with its narrow wooded island running parallel with the beach or nearly so. The fresh water swamps have a deep soft mud bottom in which cat-tails and marsh-mallows grow.

"June 18th, explored the territory beyond the railroad from the southern end of the island to near Peermont. Below Avalon, opposite the water tank, I found several ponds formed by sod having been cut out, and in those having no fish, wrigglers were found. One of the wriggler ponds was strongly tinctured with iron by hoops which lay in it; but this did not seem to affect the inhabitants. In this vicinity larvæ were also taken in brown cedar water; the first time they were ever taken in this water.

"June 19th, went to Life Saving Station No. 35, through the salt hay and sedge marsh on the way to Stone Harbor, and went out to the islands in the sedge. The islands farthest from the beach had no salt hay zone around them and an apparently well drained sedge marsh extended to the highlands. Opposite the life saving station is at least an acre of salt hay marsh cut up with breeding ponds with thousands of larvæ in them. Below the life saving station the country is practically free from salt hay, nothing but sand hills with sedge marsh to the edge of the sandy area."

I have been over this area myself on several occasions in whole or in part. With Captain Hankins I rowed from Anglesea through Hereford Inlet to the southern end of the beach and tramped to the life saving station. Just south of this station the strip of woodland begins and extends to the edge of the marsh. Here there are a number of ponds without outlet in which wrigglers simply swarm. And along the marsh edge of this highland are little coves, some an acre in extent and some only a few feet, in which millions of larvæ were wriggling in water made tepid by the August sun. A brood was just maturing and clouds of specimens followed us out on the marsh, into the boat and to the sedge islands on the west side of the Great Channel. No breeding places were found on these marsh islands, parts of which are flooded at each tide and where fish were present in every pool. The entire base of the highland fronting the marsh, to and beyond Stone Harbor, affords breeding places. In most instances a single ditch to the channel with a few small ditches from the sides, would be sufficient to drain the breeding areas and one of the worst of them needed only an opening through a narrow ridge of highland that kept out ordinary tides. On two

other occasions I made the trip from Anglesea to Stone Harbor, confirming my previous observations especially as to the safety of the sedge islands lying between the beach and the mainland. Between Stone Harbor and Avalon ditches have been cut at several points and outlets are provided for the water at the edge of the woodland. This has improved conditions and there is nothing very bad between Avalon and Peermont. The depressions between the sand hills toward the beach referred to by Mr. Viereck, do at times become troublesome and water remains long enough to mature a brood of larvæ. But sand to cure this condition is at hand and the remedy is easy.

e. LUDLAM'S BEACH AND PECK'S BEACH.

These are two narrow strips or beaches extending northeast and southwest, separated at the north from Longport by Egg Harbor Inlet, at the south from Avalon by Townsend's Inlet, while Corson's Inlet separates the two. The total length of these beaches is a little over twelve miles. At the north, on Peck's Beach, Ocean City is the important settlement; on Ludlam's Beach, Sea Isle City at about its center is the principal resort.

Ludlam's Beach was visited by Mr. Viereck, June 20th, and the stretch between Sea Isle City and the northern end tramped over. "Practically all the breeding places here are on railroad property. The pools back of the Reading Railroad were of fresh water, in depressions with a gravel bottom and a thin layer of mud. Great numbers of larvæ of the salt marsh species were found here in company with toad tadpoles. Beyond Whale Beach some larvæ were found in the cat-tail and marsh-mallow swamp. All depressions between the two railroads on Ludlam's beach are danger spots."

I have been several times at Sea Isle City and have traveled the railroad for its full length in each direction. I have also examined the marsh area on two occasions and find only a narrow strip of breeding area at the edge of the highland.

Peck's Beach is very much more broken and irregular and is a veritable nest of breeding places from end to end. Mr. Viereck made short stays at Ocean City and reports breeding places everywhere. My own experience was similar. Mr. Brehme reports as follows:

"Ocean City lies south of Longport and is probably the worst place for breeding *Culex sollicitans* for a town of its size on the

whole Jersey coast. Inspections were made through the whole town and the salt marsh south of it.

"It was at once evident that mosquitoes must be extremely abundant here as every house and barn was heavily screened from top to bottom. The soil is sandy, but water remains everywhere in depressions long enough to breed the insects.

"Many breeding-pools were found right in the heart of the town in vacant lots, and many of the gutters are in such bad shape that they are veritable pest holes. Along the Philadelphia and Reading Railroad are some very bad places and thousands of larvæ were found breeding under the station platform. Pools of water were found in back yards everywhere, and all that were examined were found swarming with larvæ."

Ocean City is an excellent example of the result of hasty, ill-considered work which made mosquito conditions infinitely worse than before the ground was touched. Only one thing can be done here and that is grade and fill in the breeding pools and put the gutter system into shape to do the work it was intended to do. Filling material is easily accesible and if every lot owner attended to his own property the cost would be insignificant, while the resulting benefit would be enormous.

The salt marsh area which lies just south of Ocean City is also a rather bad place and there are many danger pools in the meadow. But these breeding places can be destroyed by drainage and a little filling. There are little creeks and natural ditches present into which ditches might be run, and which could be connected so that the fish might run in freely to destroy the larvæ.

Several species breed on this meadow; not only all the salt marsh forms but, in addition, the species of *Anopheles* as well; the latter not at all rarely.

A dredge has been at work on the bay side for some time, and has materially improved conditions so far as its operations extend; but its area of action is too small to reach all conditions here enumerated.

The marsh between these beaches and the mainland has not been examined, nor has the edge of the mainland been investigated.

CHAPTER III.

ATLANTIC COUNTY.

a. THE ABSECON ISLAND PROBLEM.

Practically this should be called the Atlantic City Problem, since the hundreds of thousands of residents and visitors to that resort are the greatest sufferers; but Atlantic City dislikes to admit that it is infested and is really the smallest factor in the mosquito problem.

Nevertheless it is a fact that not only are mosquitoes present at Atlantic City at all times during the season, but that at times they are unpleasantly abundant along the boardwalk, on the piers and pavilions and even in the rooms of the hotels.

For several weeks all told, during the season of 1903, Mr. H. H. Brehme was detailed to make a thorough investigation of the territory extending from Absecon Island to the mainland, to Somers Point, to Ocean City and to Brigantine Beach. At several periods during the season I spent a day or two with Mr. Brehme, and during early September devoted a week to the determination of where the local supply of *pipiens* was developed.

At the northeastern end of Atlantic City, at the inlet, there is a little stretch of marsh land which contains breeding holes where a considerable number of insects are brought out. Some of these holes can be readily filled from easily accessible material, and the balance needs only a few short ditches to the Inlet or Gardner's basin. Along the line of the trolley, on both sides, there are depressed areas from the Inlet almost to the car sheds, and these fill with heavy rains and breed mosquitoes in quantity. A very little filling is needed in most of these places and there is no difficulty whatever in getting rid of all the danger spots in this section.

A much larger tract where larvæ often occur in great quantities lies north of Mediterranean Avenue, between Tennessee Avenue and Gardner's Basin, and this is much the worst nearest to the Mediterranean Avenue. This area can be ditched without much trouble, though nearest to the avenue some filling would save considerable ditching. In this section improvements are almost constant and the breeding territory becomes reduced each year. It is only a matter of time, therefore, for the complete redemption of this place, but in one year the whole breeding area could be wiped out with little trouble. So long as this territory

remains, mosquitoes will be "bad" from time to time in the city. It is the fashion to believe that a land breeze brings the mosquitoes to the shore, and that is true; but they do not come from the mainland, as is believed, because there are breeding places enough nearer by to account for all that occur.

Within the limits of Atlantic City there are no other breeding places for marsh mosquitoes on the island itself, until the Ventnor line is almost reached, and there, on the Island Thoroughfare, is a small but rather virulent breeding area which can be readily ditched, drained and made completely safe. Along the line of the railroads extending to the point where the Camden & Atlantic swings to the northwest, there are scattered breeding places between the Great Thoroughfare and Beach Thoroughfare, all of them easily drained into one or the other of these channels. Beyond that, until the mainland is reached, there is only one other small breeding place along the line of the Atlantic City Railroad. At the edge of the mainland, just south of the West Jersey Railroad to Somers Point, there is rather an ugly and extensive breeding place; but that is the only one of any account that was found along this mainland from North Pleasantville to Somers Point.

From Beach Thoroughfare northeast to Wading Thoroughfare, north to Steelmans Thoroughfare and east and northeast to the mainland, no breeding places are found. Atlantic City has no mosquitoes to fear from a north or northwest wind except what breed within her own limits. A northeaster might bring them from Brigantine, concerning which more is said elsewhere, and a west wind will carry them in from the marsh land along the railroads.

Between Lake's Bay, Beach Thoroughfare and Great Thoroughfare lies a triangular island, all marshland and not much above the ordinary tide level. This is full of small pools, most of them containing fish; but some of them, toward the center, are high enough beyond the reach of ordinary tides to dry out in early summer and become bad breeding places when refilled with rain water. One or two main ditches with a few laterals would cure this readily.

There is a small point on the south side of Beach Thoroughfare at its junction with the Great Thoroughfare where some mosquitoes breed, but that is insignificant and can be remedied by a few short ditches.

Adjoining the Ventnor line, north of the Inside Thoroughfare, is an intense breeding area half a mile along the boundary and not quite so far within it, the worst portion around a narrow ridge or island in the marsh. This can be readily drained into

the Inside Thoroughfare south of the ridge and into little natural creeks north of that point.

Ventnor adjoins Atlantic City to the southwest and is much smaller in area; but it breeds more marsh mosquitoes than the entire area within the limits of the larger city. Near the eastern line there is a small but very bad area on the south side of the Inside Thoroughfare, and that is all there is within the Ventnor limits south of that channel. But almost the entire marsh area north of that line to the Beach Thoroughfare is more or less a breeding area. In that area there are narrow ridges parallel with and close to the Thoroughfare, and especially to the north, bad breeding places are found at their base. Drainage is easy and ditches may be led to the Thoroughfare, the Ventnor Canal, Big Turtle Flat and other smaller creeks which cut the meadows and carry tide water and fish everywhere.

There is a small island between Shelter Bay and the Beach Thoroughfare, just north of that part of Ventnor lying west of the canal, and mosquito breeding goes on pretty uniformly over the entire surface. Ditches may be run to all sides and it will be easy to drain the entire area with a few good-sized channels.

South Atlantic City is even worse than Ventnor as a breeding area. For nearly its entire length a depression runs parallel to the beach dunes, followed by a ridge which begins in Ventnor, broadens through the city and narrows again before the Longport line. This ridge is also parallel to the shore line, and in the depression between them mosquito breeding places are numerous and virulent. Millions of specimens develop here under favorable conditions and drainage is not easy. It would have to be from one section into the Inside Thoroughfare and from the other in a small creek emptying into Risley's Channel at Longport. Filling is really the better remedy here and must ultimately be done before the land can be made practically useful.

Northwest of the ridge, just where it joins the marsh, there is another very bad stretch of breeding area, becoming gradually less virulent as the flat marsh is reached. But all the territory to the Thoroughfare breeds insects to some extent. This last area, however, is easily drained, for there are several creeks, as well as the channel itself, that are available for ditch outlets.

Longport has only a very small stretch of breeding marsh at its northwest corner, where it touches the South Atlantic line: elsewhere it is entirely free from danger points and the bulk of its supply comes from outside its own territorial limit. It is an easy task to drain this little marsh land into Risley's Channel.

The entire territory between Lake's Bay, Shelter Bay, Beach Creek and the mainland to Somer's Point is free from breeding places.

We have here, roughly speaking, between twenty and twenty-five square miles of marsh and water area, and of this not three square miles is breeding territory. Furthermore, so far from receiving mosquitoes from the mainland, this Absecon Island sends swarms to it with every south, southeast or east wind. It is an irresistible conclusion that practically the entire mosquito supply during most of the season for the stretch between Longport and the Inlet, is bred within the territory in which the insects are found and that local work will not only serve to give relief to the cities and boroughs mentioned, but will materially lessen the supply that gets to the mainland.

Many thousands of dollars are annually spent for improvements on this strip of territory which contains, perhaps, the most valuable seashore property in the world, and one of the factors that keep down values in Ventnor and South Atlantic City is the mosquito pest. If only a very moderate percentage of the annual expenditure for even a single year could be diverted to mosquito work, the improvement would extend to the practical extermination of the local supply of the salt marsh species.

I mention the local supply, because there are two possible sources of supply from without the territorial limits. These are, first, Brigantine Beach, whence a steady northeast wind may bring swarms; and second, the Ocean City strip, whence a southwest wind may bring a supply. Northeast winds, on which mosquitoes fly, are not common during the summer, hence Brigantine is not a serious danger point. Southwest winds are frequent, and Ocean City, in its present condition, is dangerous in the order of nearness, to the surrounding territory.

Late in the season, and especially after a long dry spell, it often happens that the marsh mosquito practically disappears and its place is taken by the common house mosquito. I noted that fact during 1903, and for some time failed to discover where such swarms could breed where no surface water was apparent. I noted that in my hotel I could keep the windows open during the night—third floor—with safety, provided I kept the fanlight into the hall closed. I noticed further that the insects were always in the halls and always in the elevators.

I noticed also in the early morning on the ceiling of a basement café and restaurant near the beach, thousands of specimens and was informed by the porter that they were always there, and got up throughout the house by means of stairways and

elevator shafts. Further questioning showed that the excavation below the flooring of the café was several feet below street level, was irregular, practically unused and that there were always pools in some parts of it. These pools are mostly surface drainage water, though there was some waste from the hydraulic elevator.

Cautious inquiry showed a similar condition in a large number of the hotels near the beach where the lower or basement floors were at or even below the street level, and the excavations below the floor not much above high tide level. The mystery was then solved because such conditions favor the development of the larvæ and explain all the peculiarities of occurrence observed by me.

The remedy for this condition lies within the power of the individual and must vary with location and conditions.

b. THE BRIGANTINE BEACH PROBLEM.

Brigantine Beach is a stretch of narrow island about six miles in length, separated from Absecon Island and Atlantic City by Absecon Inlet, and extending northeast and southwest. It is from one-fourth to three-fourths of a mile in width and mostly composed of sand hills. A branch of the Atlantic City Railroad runs to the island, there is a trolley road from end to end, and a line of steamboats connects it with Atlantic City. Efforts have been made at various times to "boom" this place and hotels and cottages have been erected, but failure has resulted in all cases, despite the favorable location of the beach, and several times the railroad has discontinued its service because of lack of traffic.

The explanation came when Mr. Brehme made a thorough survey of the island. Its surface is very irregular, made up of hills of various sizes, with depressions or valleys between. In these depressions there is more or less vegetation and a little sediment that serves to hold water and mosquito larvæ. Several large sedge areas toward the northern end have occasional tide connections and are full of holes and wrigglers. Toward this end only the salt marsh species breed, and chiefly *sollicitans*. Toward the southern end of the island there is hole after hole, depression after depression, forming one of the worst mosquito mills on the coast. Here not only *sollicitans, cantator, tæniorhynchus* and *salinarius* breed, but *Anopheles* species were found in great numbers.

The remedy for a large part of the trouble has been indicated in the description of the breeding places. The sand hills should

be leveled down filling up the depressions, and the breeding holes in the higher parts of the island should be graded out of existence. Most of the danger spots can be disposed of in this way and what remains, in the salt marsh, can be ditched or filled as seems most convenient. There is, undoubtedly, a future for this beach, but so long as the present conditions exist, few persons are likely to consider its advantages as against the necessity for fighting mosquitoes. The sum that will be required to clean out this entire island is small in comparison with the amounts that have been spent in preliminary work in other places.

The islands in Eagle Bay and on the Wading Thoroughfare have been inspected by Mr. Brehme and found to be safe.

Island Beach, two miles in length, and the territory lying between it and the mainland have not been inspected. This is the only blank from Sandy Hook to Cape May, but judging from the rest of the coast, Island Beach is probably much like Brigantine, and most of the marshy islands are safe.

c. GREAT BAY AND MULLICA RIVER.

From this marsh area extending on both sides of Great Bay, along the mainland edge of Little Egg Harbor, up the Mullica River, up the Bass River and up the Wading River, come the greatest of the mosquito swarms that overwhelm the New Jersey Pines. I have driven from Tuckerton to the edge of the marsh opposite Great Bay and have encountered swarms of the insects, have walked across the marsh in comparative comfort to the shores of the bay; have skirted the edge of the bay and tramped the marsh on the Mullica River shore, finding swarms ready to attack; have walked from the Bass River landing to New Gretna accompanied by a cloud that was kept off by citronello alone; and have driven from New Gretna to Pleasantville, always in a mob of mosquitoes. I do not believe anyone can have an appreciation of what an abundance of mosquitoes really means until he has covered this territory.

Late in July I sent Mr. Brehme into this same territory for a somewhat closer survey and he wrote me on reaching Tuckerton from Atlantic City, by stage: "What did I ever do to you that you sent me over such a confounded road. We did not use the horses to pull the stage; the *Culex sollicitans* did that; their pressure on the stage made it run all right. My newspaper was covered with blood from killing them. But we are here and will stand the battle."

Mr. Brehme went by boat to Tuckerton, down Tuckerton Bay to Mullica River; up the Bass River; up the Wading River and up the Mullica River to Hog Island. Also to the islands in Little Egg Harbor; crossed the meadows south of Tuckerton Creek; crossed Tuckerton Creek and went up two miles toward Parkertown.

The trip was made during a dry spell and on the higher parts of the marsh all the pools were bare of water. This high part is toward the shore, while the edge along the highland is the lowest part of the marsh and always wet. Not a sign of larvæ at the edges of the marsh but plenty of pools along the highland swarming with larvæ and pupæ. This general topography was identical over all the territory examined, and gives an enormous extent of continuous breeding territory in even a dry season. As a whole the marsh is very solid and haying is done over a considerable stretch of it with machines. Wherever there is a road, it cuts into the marsh and forms depressions which fill with water and breed mosquitoes. There are some ditches cut by the hay-makers, but these are usually shallow and have been allowed to become choked. They serve now as excellent breeding places in many instances; where they are in good condition they drain perfectly and no larvæ develop. On the highest parts of the marsh, along the shores of the bay, rivers and the numerous little creeks that run in everywhere, mosquito breeding seems amost impossible. A little further back from the edge the marsh is lower, becomes broken and has depressions, shallow and deep. In the deep depressions there are nearly always fishes present so that these are safe. The shallow depressions become dangerous after a very high tide that runs in through heavy grass which excludes fish. If cool, cloudy or rainy weather retards evaporation, these pools mature a large brood. The nearer we approach the highland the worse conditions become, for there the tide water soaks in, and is fairly strained of fish before it gets on the meadow.

Dr. Nelson, who studies oysters on this marsh during the summer, says that sometimes it is necessary to wade for a considerable distance from the highland to the high marsh through three or four inches of water which is absolutely swarming with mosquito larvæ. Such conditions occurring over square miles of territory give the uncountable millions that swamp the pine land. The history of one such brood as given by Dr. Nelson will be found under the mosquito migration heading.

The islands visited by Mr. Brehme are well drained, stocked with fish and fiddler crabs and without any chance of developing mosquito larvæ.

The mosquito-breeding area extends up all the rivers to the end of the salt marsh along the banks. That, in the case of the Mullica is between Green Bank and Lower Bank; in the case of the Wading it is between Bridgeport and Harrisville; in the case of the Bass it is at the junction of the East branch and the West branch. On the Nacote River, which was also explored, it extends to Port Republic and on Tuckerton Creek to Tuckerton itself. Tuckerton Creek marsh is safe, however, because the creek has been dredged out to deepen it and the dredged material has been used to level the marsh. From such explorations as were made at other isolated places from time to time, and from conditions elsewhere, it is almost certain that the edge of the highland condition found in this territory extends south to Absecon, where it joins the Atlantic City Problem and north to West Creek, where the Cedar swamp area joins the marsh area.

Here is a breeding territory greater in extent than any other in the State, thinly inhabited because of the mosquito pest, yet well enough located for a thriving population of farmers, fishermen and oystermen. The possibilities of oyster culture are scarcely even touched upon in this region, though some individual experiments are carried on.

The marsh area is traversed by numerous creeks and streams, some of them of considerable size and all of them with clean banks, carrying tide water and hosts of fish. That peculiarity of high banks and lower interior levels prevents the water of the depressed areas from getting into the streams, and the obvious remedy is to furnish this outlet. A very simple scheme of ditching will accomplish this, and in some places an enormous amount of benefit will be derived from a small amount of work.

It means the practical control of the mosquitoes in the pine belt north of this marsh area, because, from the combined observations of Dr. Nelson and Mr. Brakeley, it seems certain that in one or two nights the insects bred here can cover the distance from the Mullica River to Lahaway or Lakewood.

d. THE GREAT EGG HARBOR PROBLEM.

The marshes at the mouth of the Great Egg Harbor River and along both sides of that river for some distance inland are second in extent to those of the Mullica River only, and at least their equal in ability to breed mosquitoes. To determine just how bad these places are, Mr. Brehme was sent to run the river down from Mays Landing, which is at the head of the salt marsh territory. Mr. Brehme states that all this marsh area is draina-

ble and that the composition is such that ditches will stand everywhere. His report is as follows:

There is a very narrow strip of meadow land from Mays Landing to High Bank Landing on both sides of the river, in which there are some breeding places. They are all of small extent, none of them very bad, and can be drained directly into the river at very slight expense.

South of High Bank Landing to Steelmans Landing the meadow broadens out and contains some rather extensive and very bad breeding places. In improving this stretch it will be necessary to put in some wide main ditches to which the narrow branches could be led, for there are few natural drainage channels in this place.

On the east side of the river, extending to half a mile above Steelmans Landing, there is no marsh land whatever. Pine woodland and sand extend to the edge, and these afford no breeding places.

The area south of Steelmans Landing to Gibsons Landing on the west side of the river has some very bad mosquito territory which, however, is easily drainable, because there are many little creeks into which ditches can be run.

On the east side of the river from a point half a mile north of Steelmans Landing, extending to English Creek, there is one mass of pools. Some of these are stocked with fish and are safe; but most of them have no fish and breed ungodly masses of mosquitoes. This area has very few natural creeks, and the drainage problem is not quite so simple. It will be necessary to have some long wide ditches here to take the narrow laterals leading to all the bad spots.

Between Gibsons Landing and Middle River the meadow widens out and is from one to four miles broad. It has plenty of bad spots, but has also numerous little creeks into which they can be readily drained; so that, for so large an area, the task is surprisingly easy.

The territory between Middle River and Tuckahoe River is also a bad one, with lots of breeding places, many of which can be easily disposed of by running short ditches into the numerous little creeks that penetrate the meadow in every direction, or into the rivers themselves.

In the stretch on the south side of Tuckahoe Creek some bad breeding places have been found; but this is also a naturally well drained marsh and needs only a little intelligent work to make it safe. Inspections were continued on this side of the river from Beesley's Point to just above Cedar Creek, the same general conditions being found throughout.

The area from English Creek on the east side of the Great Egg Harbor River to Patcong Creek is another bad breeding place and filled with pools swarming with mosquito larvæ. There are several good creeks and many natural ditches in this territory which will make good outlets for the narrow drains.

The south side of Patcong Creek to Somers Point has an abundance of breeding holes and here are produced the swarms which supply Somers Point and other nearby towns. This meadow is narrow, however, and can be easily dried out, putting out of existence the source of an immense supply.

For so large and pernicious a breeding area the amount of work required to clean it up is surprisingly small and simple. There are two points only where large, long main ditches are necessary, all other parts of the marsh area being well supplied with creeks and natural ditches, from which short narrow ditches may be run into the depressed areas, draining off the surface water and admitting fish into the larger pools.

CHAPTER IV.

BARNEGAT BAY.

a. THE PROBLEM AS A WHOLE.

Barnegat Bay is noted for its fishing and its mosquitoes, and the stories told of both are equally startling. It is certain, however, that the mosquitoes have driven away more visitors than the fishing has been able to keep. From Bay Head to Manahawken Bay is a stretch of about thirty miles, while to the end of Long Beach is pretty close to a fifty-mile reach.

On the narrow strips of land known as Island Beach and Long Beach are several flourishing shore resorts and a number that are not doing so well. Several places have been started and kept up for a year or two, but few who came one year ever returned, and those that failed to return did not encourage others to go. Parties who arrived intending to remain for weeks, found mosquito conditions so unbearable that they left the day after arrival. It is not too much to say that mosquitoes have been and are the curse of the Barnegat shore, a shore which in other respects offers unequaled attractions for those fond of sailing, fish-

ing, gunning and other shore sports. The railroad service to both beaches is excellent and they are nearest in a straight line to Philadephia. Island Beach is also in direct connection by rail along the coast to New York City.

There are two flourishing points, Seaside Park, on Island Beach, and Beach Haven, on Long Beach, where an attempt has been made to improve conditions and with a fair measure of success. It is a common belief on these beaches that the mosquito supply comes from the mainland, but that is a mistake, for there are local breeding places in abundance, capable of supplying the entire strip. There is no doubt that under favorable conditions some mosquito flights from the edge of the highland will reach the beach—the evidence, indeed, is positive on that point, but such occurrences are the exception rather than the rule, and were these shore flights the only source of trouble, there would be little cause for complaint.

Along the main shore are a number of towns of considerable size and importance—Barnegat, Manahawken and Toms River, among others—and all of these suffer much from the mosquito pest.

I have covered a good portion of both of these beaches myself and have spent some days at Seaside Park and at Beach Haven exploring the surroundings in each direction. At Beach Haven considerable work was done and that is separately reported upon.

Messrs. Wagner and Mellor together or singly covered almost the entire territory with the view of determining what could be done to mitigate or remove conditions. Mr. Grossbeck covered the territory from Barnegat City to the Junction, and found the entire marsh area dry, but with numerous depressions recently filled with water, which had given out enormous swarms of mosquitoes. He confined his work to the marsh and did not get into the sand hills at all. Later he went over a section of the mainland, using Manahawken as a base, to determine the importance of the cedar swamps from the mosquito standpoint. Mr. Brehme covered the same section of the mainland, but extended his work much further south. He also explored some of the islands between Beach Haven and the mainland, as well as a section of Long Beach. Mr. Viereck covered part of the section between Bay Head and the end of Island Beach, so that, practically, I have had the whole stretch of Barnegat Bay, mainland and shore, under observation for two full seasons. The conculsion is that there is nothing especially difficult in ridding the entire shore line of the mosquito pest, provided the whole work can be done at one time. This strip of beach is somewhat pecul-

iar in that a large portion of it is sand, without much of a sod covering even on the marshes. The result is that none but the shallowest ditches will stand and these soon choke up. The easy and simple drainage by narrow deep ditching is almost totally barred here, and it becomes a question of filling. Much of that filling can be done from the sand hills along shore, but for other sections the work of a dredge would be necessary. There is no other place along the shore where breeding among the sand hills is more virulent, and where a larger proportion of danger spots can be wiped out by the simplest means.

As an illustration: From the Ortley Station to the beach there is a road between the sand hills and this road is a little above the level of the valley. On both sides is a swampy area, sometimes broad, sometimes narrow, sometimes extending into another depression to the north or south, but always in my experience with from two to six inches of water in the grassy bottom. In this water I found larvæ crowded as closely as they could be crowded and within a hundred yards of the Ortley Inn millions of mosquitoes breed throughout the season. It would be the easiest thing in the world to use the sand hills to fill up these breeding holes and Ortley mosquitoes would become appreciably reduced in even a single season by a little judicious shovel work. A somewhat similar condition prevails near Berkeley and this is in sharp contrast with Seaside Park, where the surface has been levelled and graded and local breeding places are almost entirely eliminated. As there is also an effort to keep down weeds and beach shrubbery, the adults have nothing to attract them or to invite them to remain. The result is that with virulent breeding places to the north, Seaside Park yet remains comparatively free from mosquitoes during most of the season. Not that it has no breeding places and never sees wrigglers. On the contrary, after a two days' heavy rain I went into a low meadow in which was nearly two inches of surface water, and found young larvæ just hatched in any quantity. But the summer sun and wind licked up this pool within forty-eight hours and the entire brood was killed out. And this is the fate of such broods generally, on areas graded so that only large shallow pools can form.

In his first inspection Mr. Grossbeck mapped out a line of breeding places along the bay side, extending from Barnegat City to the Junction, but the line is by no means continuous, nor of equal width throughout. Directly west of Life Saving Station No. 17, and southwest of Barnegat City there is quite a broad marsh area in which all the larger pools were supplied with

fish, but the smaller pools in great quantity offered opportunity for mosquito breeding. South of this point the marsh narrows, but at about one-third of the distance between Life Saving Stations 17 and 18, it broadens again and affords abundant opportunity for innumerable larvæ. Just west of Station No. 18 is the broadest stretch of marsh area until the Junction is reached, but most of this area is entirely safe, all the pools being large and stocked with killies. Only at the junction of the marsh and highland are there any breeding areas. Between that point and Harvey Cedars most of the bay shore is safe and part of it is highland to the edge; the little strip of marsh being mostly safe.

West of Harvey Cedars is another, considerable, dangerous marsh area, and from that point to the Junction there is a continuous strip of marsh, most of it narrow.

Mr. Brehme earlier in the season began his line of work at Beach Haven and devoted much of his time to the islands, finding them in every case mosquito-free. His work here joins his report on the Tuckerton and Mullica River district, completing that section of the cost. Mr. Mellor's report on Beach Haven fits in here and leaves the stretch from the end of the work done here to the Junction, which I covered myself, though in a rather superficial manner.

In fact, the whole stretch of Island Beach is about one kind of problem divided into two parts. First, there are the depressions in the sand hills, mostly small, but toward the bay side sometimes opening into the marsh. Second, there is the salt marsh area, mostly narrow, much of it naturally drained, but generally with a fringe of bad territory at the edge of the highland. The railroad is a factor, extending as it does almost the full length of the beach. On one or both sides of the road bed is a broad ditch and this ditch on the bay side is relieved at intervals by broad ditches led into the bay. The scheme is excellent, but unfortunately the ditches have been allowed to fill up with rubbish and vegetation, and while they serve their purpose of draining the road bed, they form excellent breeding places at many points where even the killies find it impossible to get.

The depressions among the sand hills can be graded out of existence in most cases and as much filling as possible should be, in general, resorted to. The shallow sod covering to the marshes does not lend itself to narrow ditches; it will need wide main ditches and at least foot wide laterals to do effective work and it will need attention to keep these ditches clean.

The Beach Haven account, which follows, is a sample of what will be needed to a greater or less extent along this whole stretch

of beach, and with it should be read Mr. Wagner's report on the Seaside Park area.

b. LONG BEACH.

This territory was first thoroughly explored by Mr. Viereck between May 15th and 23d, at a period when the first brood was on the wing in great numbers and the second brood had not yet made a start, owing to unfavorable climatic conditions. The territory covered extended from Chadwicks to Life-Saving Station No. 15, and the report is chiefly on the physical characters.

I had already, in 1902, covered a considerable portion of this same territory, and as it seemed to require a still closer study I assigned Mr. Wagner to the task and give his report as follows:

Report on Territory Extending from Chadwicks to Barnegat Inlet.

In this report I follow the notes I took as I walked through the territory. I started from the Pennsylvania railroad, where it crosses the bay, and worked north to Chadwicks. Then, beginning at the railroad again, I worked south to Barnegat Inlet.

(1) In the territory extending 300 feet in from the bay and 1,000 feet north of the railroad are five or six depressions which collect rain-water and become breeders. No ditching is possible, as the soil is all sand; the shore and the bay bottom are sand.

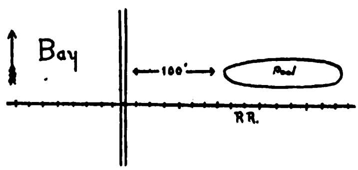

Figure 126.

(2) The pool here is 300 feet long and 15 feet wide. It breeds profusely. Filling is necessary here.

(3) From Seaside Park to Berkeley, west of the railroad, the land is swampy, with some dry spots. There are not many wrigglers. The soil is sandy. The shore and the bay bottom are sand. No ditching possible.

(4) East of the railroad the ground is covered with bushes and generally good, so my work was confined mainly to west of the railroad. Going north from Berkeley, for 400 feet is dry sand, then 600 feet of swamp ground. Found no wrigglers, but conditions favorable for them. Near Life-Saving Station No. 13 ditches can be dug, but the shore and the bay are sand, making it impossible to lead the ditches out.

(5) Fifty feet north of Ortley Station and close to the east side of the railroad is a large pool, where breeding goes on plentifully. This place is responsible for Ortley's mosquitoes. It should be filled. On the south side of a foot-path from Ortley to the bay and fifty feet from the bay is a bad depres-

sion—not large, however. It needs filling. Ditching here, as in the rest of the places, is impossible because of the sandy character of the soil.

(6) From Ortley to Lavalette, on both sides of the railroad, water has collected on account of the embankment of the railroad. Breeding goes on. Filling is necessary.

(7) In the southern part of Lavalette, along Pennsylvania avenue, a road has been built up. On each side of it are holes containing larvæ.

(8) From Ortley to Lavalette, on both sides of the railroad, there is a thick growth of bushes. The land is generally dry, but in many places, on moving back the foliage, little holes, 1 to 2 inches deep and 6 inches in diameter, are discovered, full of larvæ.

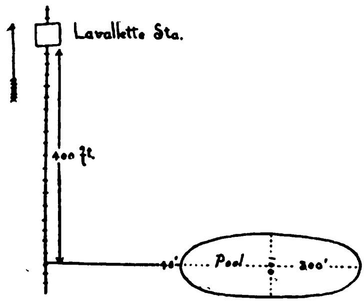

Figure 127.

(9) This pool has grass in it, and three inches of water. I found it full of larvæ. It should be filled.

(10) Between Lavalette and Chadwicks are many creeks which overflow and wet the land. One thousand feet south of the Chadwicks station is a dug ditch for haying purposes running from the railroad to the bay. Where the hay is cut are holes six inches in diameter with three inches of water. These holes contain wrigglers.

From Lavalette to Chadwicks the soil has less of a sandy character, being more swamp-like and covered with tide-water.

North of Chadwicks the neck of land becomes very narrow, cut into by creeks and inlets, and marsh-like in nature.

(11) After going north to Chadwicks I started from the railroad south to Barnegat Inlet. From the railroad, where it crosses the bay to South Seaside Park, for 600 feet in from the bay the ground is variable in character. Some parts are dry sand, others have grass with water present and breeding going on sparsely; still other places are covered with thick bushes growing in water often six inches deep. The shore and the bay bottom are all sand, making ditching into the bay impossible. This is true all the way to the Inlet. On either side of a path leading from South Seaside Park to the bay breeding is in great evidence.

(12) For about 1,300 feet below South Seaside Park, extending to within fifty feet of the shore (which is solid sand), there is a swamp covered with four inches of water. In the main body of the swamp breeding is not general, taking place in spots where there is a break in the grass-growths. But at the edges of the swamp are holes not over two feet in diameter which are bad breeders.

(13) From here on the ground becomes high, trees grow, and bushes, clear to the edge of the bay. Half way between the ocean and the bay, and 100 feet north of Reed street (which leads to Life-Saving Station No. 14), is a large pool in among the trees. No breeding goes on in the pool, but in holes at the edges of the pool, larvæ are present.

(14) On the north side of Reed street, 150 feet west of Station No. 14, is a pool extending 200 feet north. Breeding goes on here. The place should be filled.

(15) From Station No. 14 south are many large sand-hills. As a rule, the sand between them is dry, but where three-square grass occurs I found the ground always moist. It is quite probable that heavy rains will cause the water to remain here long enough to permit breeding.

(16) After I had gone through the territory reaching a mile below Life-Saving Station No. 14 I sailed down to the Inlet and walked back. For one and one-half miles up from the Inlet, sand, covered with trees and bushes, stretches from ocean to bay, and is good territory. From here on I first zig-zagged diagonally, going from ocean to bay, then to ocean again, and so on. But I always found it dry where trees and bushes were, which was the major part of the land, and bad only along the bay shore. In a few places there were small depressions among the bushes, but not enough to take account of.

(17) A swamp begins three-quarters of a mile south of Life-Saving Station No. 16 and extends up to Station 16. I have drawn a rough sketch of the swamp.

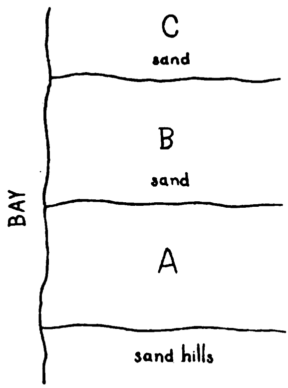

Figure 128.

Station 16.

The bad places begin 400 feet in from the bay. The swamp is divided into three parts—A, B and C—by two sand ridges. A is generally submerged. B and C are comparatively dry, but have bad holes. This swamp is ditchable, but ditching is not worth while, because east of the swamp and separated from it by mounds of sand are bad wet places, which cannot be ditched. Comprehensive grading alone will suffice.

(18) For 1,000 feet north of Station No. 16 the ground is generally good, an occasional bad hole occurring. Then another swamp begins, extending 1,000 feet north and 600 feet in from the bay. The first 500 feet are bad; the other 500 feet fairly bad. The ground is sand, with just enough soil for grass and bush to take hold.

(19) For 300 feet north of this swamp is good ground covered with bushes; then 300 feet of swamp that breeds, like (18).

Then 200 feet of good ground.
" 400 " " swamp, like (18): breeder.
" 300 " " good ground.
" 500 " " bad places, extending 200 feet in from the bay.
" 250 " " dry ground, with bad holes two feet wide.
" 100 " " good ground.
" 800 " " dry ground, with occasional bad holes.
" 100 " " good ground.
" 600 " " variable land, some places dry, with brushes and gress; also depressions that breed.

From here there is a swamp that goes 1,000 feet north and extends 400 feet in from the bay. It is not generally bad, but in places it is.

(21) From here north the land is like that noted in (20). At a number of places there are inlets from the bay, the mouths of which have been stopped with sand, preventing a rise and fall with the tide. The main water in the inlet does not breed, but at the edges there are always isolated holes, which are profuse breeders.

(22) Except for the swamp near Station No. 16, the entire territory from the inlet to the railroad is sand. There is not soil top enough to maintain a ditch.

(Signed) CHARLES WAGNER.

The conditions reported by Mr. Wagner differentiate this territory from nearly all the rest of the shore, in that ditching is completely cut out as a method of obtaining relief. In many places the depressions have only a thin but tough coating of vegetable matter that serves to hold the water long enough to permit mosquito larvæ to develop. By far the greater number of these depressions are amenable to shovel work from the surrounding sand-hills, and that is especially true of the conditions at Berkeley and Ortley; but along the bay shore the hydraulic dredge is necessary to secure relief. As the bay is all sand, and there are no long distances to be covered, even a small dredge could accomplish all the necessary work in a single season.

To complete the work at the head of the bay and continue it along the main land, I sent Mr. Brehme, who reports as follows on the territory between

Manasquan and Mantoloking and Bay Head to Island Heights.

Inspection made on the area between the United States Life Saving Station No. 9 on the east, Brielle on the west, Manasquan Inlet on the south and Manasquan on the north, resulted in finding some mosquito breeding places of little account, comparatively speaking. These places are mostly near the Manasquan River, and it will be easy to drain them into that place by short ditches that will admit live water and fish into the breeding pools. None of them are of any considerable extent.

On the south side of Manasquan Inlet to Point Pleasant there is very little breeding area. There are a few places near the inlet and there is a place at the end of Cook's Pond. All these can be cleaned out by drainage into the inlet and pond respectively.

There is a small breeding area on the northwest side of Twilight Lake which can be readily drained. The lake is fed from the Metedeconk River, is well stocked with killies and affords a good outlet for ditches.

The stretch from Bay Head to Life Saving Station No. 11, about a mile south of Mantaloking, was thoroughly inspected and breeding places were found on all the salt marsh area between these two points. But the strip of marsh land is very narrow and very little work is required to drain it perfectly into the Metedeconk River and Barnegat Bay.

The area from Bay Head to Wardell's Point, on the mainland, also contains a number of breeding places, which can be readily drained into the river.

On the south side of the Metedeconk River to the north side of Kettle Creek there are a lot of mosquito pools, the greater portion of them lying close to the highland. While there are many places on this territory that bred countless thousands of the insects, it will, nevertheless, be easy to dispose of them, because the marsh is cut up by tide creeks, all deep enough to afford excellent outlets for ditches, so that in most instances the breeding areas can be readily drained into a nearby creek by a short ditch.

The area between Kettle Creek and Mosquito Cove has a number of bad spots, but there is only a narrow strip of marsh and it can be very readily drained into the bay.

From Mosquito Cove to Island Heights on Toms River matters are worse than they are further north and many bad stretches were found. But all of these can be readily drained into either Goose Creek or the bay itself, good outlets for ditches being offered by both.

Good Luck Point, Toms River, to Mill Creek, South of Manahawken.

Inspections made between Good Luck Point and Cedar Creek resulted in the discovery of so many breeding places that it may be said that the entire salt marsh there is a danger spot. The marsh is about half a mile wide, but is cut up by creeks and natural ditches so that no part of it is very far from tide water. All these natural water courses are deep enough to serve as outlets for ditches and to drain two-foot ditches completely at low water.

The territory between Cedar Creek and Forked River is of the same general character as the preceding and offers opportunity for breeding enormous swarms of mosquitoes. The marsh is wider than the one just north, but is equally well provided with deep creeks which would serve to receive ditches for draining the bad pools. Killies are abundant in these creeks, and if con-

nections are established between them and the breeding pools, the fish would provide against any possible development of larvæ.

Inspections were then made from the cedar swamps on the south side of Forked River to the end of the salt marsh on Oyster Creek. The cedar swamp on Forked River contains numerous fresh-water pools which would seem to be ideal places for mosquito development, but the very closest collecting failed to discover even a single wriggler. On the very edge of the cedar swamp the salt marsh begins, and not more than ten feet away both *Culex sollicitans* and *cantator* were found breeding in enormous numbers. A great many bad breeding places were found here, all of which could be drained into Forked River, Oyster Creek or one of the several other smaller creeks which empty into Barnegat Bay.

Between Oyster Creek and Waretown Creek is a narrow strip of marsh land, and what breeding places occur here can be easily ditched into the creeks or directly into the bay. There are no physical difficulties and, if judiciously placed, the number of ditches needed is not very large.

From Waretown Creek to the main road at Barnegat many breeding places were found; but this also is easly cured, because for two miles south of Waretown Creek the meadow is very narrow and drainage is into the bay itself. For another mile, from the end of this narrow marsh to the main road at Barnegat, the meadow is a great deal wider, but there are a number of deep creeks which would serve as outlets for such ditches as might be needed.

Breeding is bad from the main road at Barnegat to the Gunning River, but this breeding is on the mainland and not on the sedges which run far out into the bay. A number of creeks and ditches—line and natural—cross this area; but the ditches are so grown up with grass and weeds that they are of no present account. If they were cleaned out and made serviceable once more, this territory would be at once greatly improved.

South of Gunning River is a large cedar swamp which is so dense that it is almost impossible to get through it. No larvæ were found, despite close search. Adults were plentiful, however, and many were captured and examined. All were of the salt marsh species, *sollicitans* and *cantator*. At the commencement of the salt meadow bordering this swamp, extending down to Manahawken Bay, is one mass of breeding places. Mosquitoes develop here in enormous numbers, and drainage is not so easy because of the great width of the marsh and the absence of natural drainage creeks. It will be necessary to provide several wide

ditches each over a mile long, three feet wide and three feet deep to serve as outlets for lateral drains through the intervening territory. This is the worst and most extensive breeding area on Barnegat Bay and supplies swarms for the inland as well as some to drift over the bay and reach the shore strip.

The stretch from Manahawken Creek to Mill Creek is another bad area on which breeding is continuous down close to Manahawken Bay. There are two good creeks on this meadow, however, which simplify the drainage problem and will serve to receive the ditches. Manahawken Bay is also available for this purpose.

The cedar swamps at Manahawken are as free from mosquito breeding places as those further north, and no larvæ whatever were taken in them.

The islands in Barnegat Bay are all free from breeding places except Clam Island, which has a few places. Very little work would be necessary here, however, to clean out the entire area and make it permanently safe.

Many breeding places have been created by the Central Railroad from Barnegat Park to Barnegat, and just as many by the Tuckerton Railroad from Barnegat to Manahawken. Inspections were made along both roads and many of the places where dirt was dug to make the railroad embankments are now filled with surface water and breed fresh water species like *Culex sylvestris, canadensis* and the *Anopheles species*. The ground here has a clay subsoil which holds water a long time and, indeed, untill it evaporates. The only thing to be done here is to refill the places.

Mr. Grossbeck also explored the Cedar swamp area near Manahawken in a search for the larva of *Culex perturbans* which was believed to breed there; but his report is the same as Mr. Brehme's; no mosquitoes breed in the Cedar swamps and the adults found there are either *sollicitans* around the edges and in the more open portions, or *cantator* in the more dense, darker places.

From these reports it appears that Barnegat Bay well deserves its reputation as a mosquito breeder and that along the beach the problem is more complicated and difficult than in any other part of the shore. On the land side, however, the simplest kind of drainage suffices except at Manahawken. Some of the breeding areas are so prolific that even a little work would produce marked good results.

c. THE BEACH HAVEN WORK.

This is really a part of the Barnegat Bay problem; but is separately dealt with here, partly because Beach Haven was one of the first sea shore places where practical work was attempted, and partly because considerable work was done under the supervision of, first Messrs. Wagner and Mellor, and later of Mr. Mellor alone.

Early in the season of 1903 Mr. Brehme covered the ground in a general way and located breeding areas on the shore strip. In 1902, I spent two or three days as the guest of Mr. R. F. Engle, at the Engleside. It was the general belief at that time that the mosquitoes which were sometimes very troublesome were a main shore product and came in with a west wind. When there was a sea-breeze there were few or none. The facts were correct, the explanation erroneous. The mosquitoes did really come in from the west but only for a few hundred feet; because on the bay shore there were acres of breeding territory of the most attractive kind. These were pointed out to those interested and the promise was made that in 1903 if the State authorized the investigation the surroundings of Beach Haven should receive attention. Mr. Brehme, therefore, did not confine his survey to the seashore strip, but examined the islands and part of the main land as well.

Mr. Brehme's conclusions were, at the time, that the main land had little to do with the Beach Haven supply and Mr. Engle was encouraged to secure local action.

Early in July, Messrs. Wagner and Mellor were assigned to lay out the plan for clearing the infested area and to render what assistance they could. Mr. Engle was the moving spirit in the work and his courtesy in accommodating the assistants at the Engleside, added materially to their comfort.

The report and the accompanying maps show what was done, what time was spent in doing it, and what remains to be done.

It needs only to be added that as a reward for his efforts on behalf of Beach Haven, Mr. Engle was defeated for re-election to the Council because he had favored spending borough money for the mosquito work.

Report on the Work at Beach Haven and Vicinity.

The work at Beach Haven and vicinity was done between the sixth (6th) and twenty-eighth (28th) days of July by Mr. Wagner and the undersigned, and between the fourteenth (14th) and the twenty-fourth (24th) day of August by the undersigned alone. The work consisted of a general survey

of the territory, of staking out ditches where necessary and where the ditches were to be dug immediately, or in the near future, and of general superintendence of the work of digging the ditches.

General Survey.

The general survey was carried on from a point two miles north of the Little Egg Harbor Inlet (near the twenty-third Life-Saving Station) to the northern limits of Spray Beach. The territory near the twenty-third Life-Saving Station has many breeding places, consisting of pools in the sandy parts and of marshy ground, which is suitable for ditch work. Moving northward, the territory is generally good, being sandy, or covered by high tide, bringing fiddler crabs, or small fish, into the places where water collects until the Holgate property is reached. There is a need of ditching on this property. On the west (Bay Side) there is a marsh area. Then comes the Sherburne property. On this there is much breeding area. The need is ditching. Some has been done and will be referred to. Still north is Beach Haven. In Beach Haven many breeding spots were found. The problem is to be solved by ditching on the bay side and filling in depressed spots in the town and by filling up the holes among the sand hills on the ocean side. North Beach Haven comes next. Here there is a marsh on the bay shore which should be ditched. North of this is Spray Beach. The problem is simple at this place. A little filling in a very few small places will make this part good. Immediately north of this is the Newbold estate, on which there is some breeding area which should be ditched. Along the railroad, from Beach Haven northward, pools in which there is mosquito breeding are of frequent occurrence. These pools are on railroad property, if the railroad owns thirty feet on each side of the track.

Staking and Ditching.

Nothing has been done south of the Sherburne property for the extermination of the mosquito. On the Sherburne property, west of Bay Avenue and between Norwood and Berkeley Avenues, there has been 1400 feet of good serviceable ditching done. There are 366 feet of ditching in this same area which is not good. The trouble is that the ditches are not cleanly dug and that they are not deep enough. They are but five or six inches deep, and they should be at least ten or twelve inches deep. South of Norwood Avenue there are 2068 feet of ditching staked out but not dug. The territory through which these ditches are laid out is very bad. During our entire stay there was never a time when the ground was wholly free from water. On both sides of the road there are chronic pools. The stakes for ditching have been laid in a manner which will relieve most of these pools along the road. Some of the pools must be filled in. A sluice box is necessary under the road near Norwood Avenue and can be located easily by the position of the stakes on the sides of the road. There is other territory which should be ditched but which is not staked because it was our purpose to stake only as much territory as would probably be ditched in the near future. The breeding area not staked, however, would take about a thousand feet.

North of the Sherburne property is Beach Haven. South of the Bay Road and west of Bay Avenue, marked (A), in the Borrough of Beach Haven, 11,835 feet of good ditching has been done. In that part of the territory nearest the road marked (A) there remains 2080 feet of ditching staked out to be dug. During the second trip to Beach Haven this territory was examined and the ditching proved very effective. There were some small places which need further treatment and the ditches should be gone over to remove one or two blocks of sod which have been neglected. There was no breeding going on, however, except in the section described as having ditches not

dug, and there several places were found in which breeding was going on. The tide came up into these ditches at every high tide. Crabs and fish were in abundance. In this section (A) is the water tower, and a little south of the water tower there is a pile of lumber under which there is a constant pool which is also a breeder. Across the road is a section marked (B) where 2800 feet of ditching has been done. In the section marked (B) there yet remains 350 feet of ditching staked out and not dug. The ditches in section (B) depend upon a sluice under the Bay Road for an outlet into tide water. This sluice is not as low as it should be for perfect drainage. To overcome the difficulty, a hole was dug at the sluice a foot deeper than the ditch, to form a sort of retreat for the fish which came up at high tide. The result is this: The fish enter the ditches at high tide and remain in the ditches continually, so that although all the water does not pass off at every low tide, there is a constant supply of fish to keep the ditches free from possible breeding. The water completely fills the ditch at high tide near the sulice box under the road, and gradually becomes more shallow in the ditch. The ditches in section (B) were dug between our July visit and my August trip. But they were not dug deeply enough. They had to be done over again. During the August trip a sluice box was put under Bay Avenue to make an opening for the ditches on the eastern side of the avenue. Before any ditches were dug in section (B) it was a terrible place. On two-thirds of the area there was not a square yard which under proper conditions was not a breeding place. After two weeks or so of dry weather section (B) would partly dry out. Then a rain ould flood it again, and with the water came the hatching of the eggs of *Culex sollicitans,* and in a few days a harvest of mosquitoes. This is not a statement of what might happen, but of what we actually saw. The ditches were dug and finally made deeper, as described above, and I watched the place during the August visit and found that the water, in a day or so after the rain, had disappeared from the surface of the ground not more than damp. This effectually checked the breeding on this section. There were a few small holes in the northeast corner which needed ditching and the stakes were put in. There is a road from the railroad station to the Bay Road between section (B) and the railroad track. This was repaired by the railroad company and a ditch was dug in section (B) parallel with the road and about five feet from it, connecting without ditches. The filling on the road was well done. The ditch was well placed but it was left full of loose and ragged sod, which hindered the flow of water and the passage of fish. At the extreme end of the railroad there is a house which is used as a storage place for oysters. The house stands on piling and beneath it there is a pool which was found to be a constant breeder. The place should be filled in. Going north along the railroad there are places on the east side of the track, between sections (B) and (C), which need to be ditched. The ditch along the railroad track at this point is of little or no service. If the ditch along the railroad were cleaned out, the breeding places could easily be treated. On the west side of the railroad up to this point, between sections (B) and (C), the territory was found to be good and safe. In section (C) 935 feet of good ditching has been done. In this locality there still remains 400 feet of ditching which has not been dug, but which has been staked out. Most of this was staked out during the August trip. This section was also a very bad place. There were pools which at times had so many larvæ in them that there appeared to be a shadow on the water. After the ditches were dug, I visited the place many times and in the locality of the ditches there were no pools, and consequently no breeding. There were other pools several hundred feet away which had not been treated and it was for these that I staked out ditches. These last pools were found to be very bad, and are located at (C) on the sketch. They are chronic pools, diminishing in dry weather and swelling after a rain, thus forming a constant breeding ground. The section (C) is at the northern boundary line of the Beach Haven Borough. North of this boundary line (North Beach Haven) no ditching has been done. The breeding area has been staked out as shown in section (D). North Beach Haven has a small population, and from present indications

this is not very active in the work of mosquito extermination. I did not pace the amount of ditching necessary in section (D), but judging from the marshes I did pace I would estimate that there are about 15,000 feet of staking done. The proposition at North Beach Haven is one of ditching. To the inexperienced eye, the territory at a dry season would appear very harmless. The grass would be dry. The mud holes dry, and even larger pools being dry might argue that the place was in a safe condition and that no staking was necessary. But if the territory was visited a few days after a rain, the conditions would be greatly changed. Pools, both small and large, would be found everywhere. Larvæ would be abundant. Still a few days more and a very uncomfortable flight of mosquitoes comes from this innocent looking territory. When we first visited this territory (D) the conditions of dry weather prevailed. We found adult mosquitoes in the grass but very little water and no larvæ. We naturally judged that the adults were from a former crop. When we began laying the stakes some rain had fallen. The holes were filled with water. The larvæ appeared in great abundance, and when we were finishing the staking the work was done with the greatest discomfort because of the mosquitoes which had issued from the pools, and in many places we saw patches of the insect which had not yet left their native pools. If the ditches which have been laid out are dug, and dug with proper depth and are left clean, the pools which are formed with every rain will pass off before any breeding can be complete; that is, before the larvæ can mature. Of course, it is plain to any one that if the mosquito gets no further than the larval stage we are satisfied, for in that case there will be no mosquito from such a source. The presence of water for two or three days is not a matter of great concern, for in that time larvæ would be the advanced stage of the breeding, and if the water were to pass off the larvæ die and the end of the breeding has come. Thus since the ditches laid out in section (D) will take off the water accumulated by the fall of rain or by a possible high tide, in a few days (two or three days) the breeding in that territory must cease, when the ditches are dug. Along the railroad, near section (D), there are choked ditches. These were built for drainage purposes, but they have lost their use. They are choked with a growth of grass and should be cleaned out. The outlet of the ditches along the line of the railroad is a ditch through section (D), but this outlet ditch has lost its flow by the growth of grass. The railroad ditches are dug wider and shallower than those dug for the purpose of mosquito extermination and are more readily choked with weed growth. A sluice box should be put under the railroad at the northern boundary of Beach Haven to make an opening for a ditch which should be dug parallel to the boundary and a few feet south of it.

During the second (August) trip to Beach Haven I spent a day at Spray Beach. Between Twenty-third and Twenty-fourth Streets, near the railroad, I found several small pools on the graded territory, in which breeding was going on. These could easily be filled in. At the junction of Beach Avenue and the northern limit of Spray Beach there was a bad pool. This should be filled. Near the railroad and the northern limit were some bad places. These could be ditched or filled with slight expense. If these few places were filled Spray Beach proper would have no breeding area. North of Spray Beach and near the bay there is a bad strip of territory. It is on the Newbold Estate. The estate has about forty claimants, about five of whom visit the property as a summer home. Nothing has been done on this property in the way of staking since no immediate ditching was expected. Something should be done on the estate. A ditch under the railroad would be necessary at the southwest corner of the estate, the position of the sluice box being marked on the sketch.

On the ocean side the breeding places are located on the Beach Haven property. They are found in the section marked (F). The territory consists of sand hills and intervening places which retain water. These pools could easily be filled with the use of a drag. The material is close at hand. The sand hills and pools are very close together. The breeding in these pools was constant and abundant. At the corner of Beach Avenue and

Fourth Street there is a lot which was very bad. Filling in is the necessary work there.

The Borough of Beach Haven hired a gang of Italians and two natives of the place to do the ditching laid out. Our first instructions were to lay out so much ditching as would be done during the past summer. This we did with a surplus. But it was found necessary to do more than stake out ditches. The purpose and size of the ditches was new to the laborers. Supervision was necessary and was given. The section (A) dug by the Italians and the sections (B) and (C) dug by the natives are examples of what good ditching will do in an infested country. The ditching in section (B) had to be gone over twice, since the ditches were not dug deep enough the first time. This, of course, added to the expense. Beside the supervision of the ditching, the use of oil was seen to, so that two broods were largely destroyed. We thus added to the object of staking bad territory, the purpose to see the work successfully done. The results of the work have shown that Beach Haven gets its mosquitoes from local breeding areas and not from some outside source, across the bay, for instance. The work has also demonstrated the practical value of the methods employed, that is, ditching or filling bad territory. I do not include oiling, because at this late day it is generally understood that the use of oil is but a makeshift and to be used only where temporary relief and a quick method is sought and where a single crop is to be destroyed.

The proposition at Beach Haven is an easy one. From the ocean there is, of course, no concern. There is but a narrow strip of land southward. We have no reason to believe that Beach Haven suffers from mosquitoes which have been carried by winds or have flown across the bay from the mainland. Northward there is also but a narrow strip of land. We know that the supply of mosquitoes from the local breeding grounds is very large. The distance to tide water is very short. The majority of the marshes are composed of the heavy sod which makes such fine support for the sides of the ditch, so that when once dug, with a little care, they will last and remain serviceable. The millions of larvæ which passed through the ditches when they were first dug and later the absence of water in old pools such as in sections (A), (B) and (C) show the practical value of the ditches.

Respectfully submitted,

November 20, 1903. (Signed) JOHN MELLOR.

CHAPTER V.

THE SHREWSBURY RIVER WORK.

One of the first communities along shore to take up the question of mosquito extermination was Monmouth Beach, and at the invitation of Mr. Eugene Winship I visited that place during the summer of 1902 and several times in 1903, to look over the ground, advise and in general to give what assistance I could. Mr. Winship's history of what was done and how the work gradually increased is told in his own words a little further on.

Figure 130.

Shallow ditching at Beach Haven. The turf is not over 12 inches deep in many places and that limits the depth. (Original.)

In 1903 I had Mr. Brehme survey the area from Sandy Hook point to the mainland at North Long Branch, both shores of the Navesink River and both shores of the Shrewsbury so far as any salt marsh could be found.

The shores of Sandy Hook Bay from the Atlantic Highlands to the Navesink River are abrupt and offer no marsh breeding places. Both shores of the Navesink are equally safe and the few islands and marsh areas in and along it have no mosquito pools.

Sandy Hook extends nearly five miles into the ocean, parallel with the rest of the coast and, for four miles, nearly, there is more or less salt marsh on the western or bay shore of the strip. Practically the entire mosquito supply of Sandy Hook—not a small one by the way—is bred within the limits of the government reservation and this fact was pointed out to the commanding officer and post surgeon. It was by courtesy of the commander that permission was obtained to survey the reservation, and it was found that the worst breeding place on the strip was within a short distance of the hospital. It was indicated that all this would be attended to, and at any rate there is not the slightest necessity for a single salt marsh mosquito on the Sandy Hook strip. The places that occur, though very bad and prolific breeders, can be easily drained or filled.

This leaves the Shrewsbury and its various inland extensions like Pleasure Bay, Blackberry Cove, etc., as the only source of salt marsh species for the Monmouth shore. Eliminate these and the whole territory is beyond the reach of salt marsh migrations.

Having determined these points, reports were presented to the associations concerned and permanent work was urged. During the winter the project assumed concrete form and, in February, Mr. Brehme was again sent over the ground to lay out, roughly, a ditching plan to clean the breeding territory.

This rough plan was submitted to Mr. Wagner, who went over the territory as engineer and approved it. Based upon this plan estimates were obtained and contracts awarded. Mr. Winship's history touches upon this, and so does Mr. Brehme's report which also follows. Mr. Brehme, by the bye, was assigned to represent the office and see that the work was well done, since both associations insisted upon its approval by me before making payments.

Within the treated territory the work was completely successful and there were practically no marsh mosquitoes on Monmouth Beach or Rumson Neck during the summer. There are some upland breeding places yet present on Monmouth Beach and vicinity; but these are being hunted out and safe-guarded as fast as possible.

It is difficult to find and reach all these little local danger points and a circular letter was prepared and widely distributed to interest individuals. This letter is also reproduced here and was issued before all the work of the season was completed.

There remain some marsh breeding places within the jurisdiction of the associations referred to here, and from them a supply of marsh mosquitoes may get into the mosquito treated territory. But efforts are being made to secure action by the municipalities concerned, and if that is accomplished there is no reason why marsh mosquitoes should not be completely eliminated on the Monmouth shore.

Mr. Winship's contribution is as follows:

Mosquito Suppression at Monmouth Beach.

Monmouth Beach is considered the garden spot of Monmouth County. It lies half way between Seabright on the north and North Long Branch on the south; the Atlantic Ocean on the east and the Shrewsbury River on the west complete the boundaries of the most popular resort on the coast. The summer residents and property owners are composed principally of bankers and brokers. The government is local; Long Branch City and Seabright have no jurisdiction within its boundaries. The property owners pay for all improvements and sustain the running expenses by individual subscription. They also maintain a club house, country club, golf club and a church, water the roads and light the same. In addition to the above they pay for their own fire and police protection.

Situated about forty miles from New York City, with the excellent facilities for travel furnished by the Central Railroad of New Jersey, it requires but an hour and forty-five minutes to cover the distance. Possessing every advantage but one, and that one detracting in a measure from making Monmouth Beach the ideal summer resort. Monmouth Beach was not mosquitoless; in fact, the pests became so troublesome that a summer resident and property owner, Mr. H. D. Cooke, realizing the situation and fearing Monmouth Beach would lose its prestige as a summer resort, began to seriously consider whether it was not possible to suppress the annoyance to such an extent as to make life bearable to the community at large.

After obtaining all the information possible on the subject, the above-named gentleman consulted with his neighbor Col. William Barbour, and they mutually agreed to inaugurate a crusade against the pests. Having adopted a plan, it was deemed advisable to commence operations at once. Circulars stating the object were printed and mailed to the property owners, requesting a subscription to commence the work. This was in the year of 1900. The response to the circular was not very generous; the majority of the residents ridiculed the idea and claimed that they had no money to throw away on such tom-foolery.

However, enough funds were obtained to warrant the execution of the plan that had been adopted It was decided that the spreading of oil upon the infected places would probably prove effective in exterminating the larvæ, thereby decreasing the supply of adults. Immunity from the pests was the aim of the committee. Health and comfort was the watchword. The aim has been accomplished and the same watchword prevails. Oil was procured from the Standard Oil Company and a man engaged to spread the same in stagnant pools and salt holes on the meadows. In a small way the work was successful. The man engaged to spread the oil was conscientious in the dis-

charge of his duties, and became quite proficient in finding and destroying the mosquito larvæ. At this time the committee were badly handicapped. With only one man and a small quantity of oil, owing to the scarcity of funds, it was hardly to be expected that any great relief should be felt at Monmouth Beach. It was simply impossible under the above conditions to cover the territory that contained the breeding places. But the oil did its work and the larvæ were destroyed in the pools, whether fresh or brackish, in which it was placed. The committee were not discouraged and determined to continue the crusade the following year, commencing the work a little earlier if possible. They were also determined to obtain a larger sum of money.

In 1901 the same plan was adopted, circulars were mailed, and the responses in the shape of checks were more generous than the preceding year, showing very plainly that a few had given the matter serious attention. Their education had begun, and to-day many of our residents are enthusiasts in the cause, giving generously of their time and substance. Three hundred and ninety dollars ($390) was the amount subscribed to propagate the work in the year 1901; a sum totally inadequate to obtain the desired results under the natural conditions of affairs. Mr. Jerolaman, a boat builder at Galilee, was persuaded to supervise the work and his nephew was engaged to spread the oil. The results were not as successful as they should have been, owing to the incompetency of the men employed. However, Mr. Jerolaman in his report states that there is no doubt that millions of larvæ were destroyed, but owing to the number of places that were not treated the results were not satisfactory. In this campaign $343.54 were expended for service and oil, leaving a balance of $46.46 in the treasury.

The writer of this history became interested in this work from its commencement; experimented with the oil that was being used until he became perfectly satisfied that the desired results could be obtained, providing funds were contributed to purchase the oil and maintain men enough in the field to make the work effective; yet it was very evident that the work would be only temporary, requiring the same expenditure year after year. Permanent results were desired; but how to obtain the same? The writer finally decided to get rid of the breeding places wherever possible by adopting Prof. John B. Smith's plan. Ditching, draining and filling in was the "Open Sesame" for a mosquito community.

It was early summer in the year of 1902, and the campaign had not as yet been opened. The committee who had been directing the work were becoming anxious, and at last decided to enlist the servics of the writer and to commence a crusade against the mosquito pests that would be remembered for many a day.

In order to make these few remarks as intelligible as possible it would be well to understand that west of Monmouth Beach and extending from North Long Branch to Low Moor the salt meadows predominate. It can be readily understood that the meadows were the breeding places of the vast numbers of mosquitoes that infested Monmouth Beach and vicinity, making life unbearable for the residents and causing a notable decrease of cottage rental. There is no doubt that property depreciates in value in mosquito breeding localities. From a financial standpoint, money invested for mosquito extermination pays largely, as it tends to increase the value of real estate 100 per cent. A hard headed business man can readily understand an argument of this kind.

After a conference with the committee, the writer agreed to undertake the management of the work. The committee at once issued a bulletin to that effect and asking for a liberal subscription to continue the work. Under the new management the work was rushed and an attempt was made to systematize the same. The localities to be treated were divided into districts, and each district placed in charge of a competent man; there were five districts, consequently five men were engaged to do the work. A foreman was also employed to supervise the whole. There now sprang into existence the first association of its kind on the coast. The members were H. D.

Cooke, Col. William Barbour and the writer. The writer was appointed manager, secretary and treasurer. It was called the Monmouth Beach Improvement Association and its object was the suppression of the mosquito pest. From this time the active duties of the writer began, and the results that were obtained from a temporary standpoint were satisfactory. Every foot of the meadow and the surrounding territory was examined, and the breeding places located. The men were assigned to their several posts and the work prosecuted with the utmost vigor. About this time the effort to obtain the desired results seemed impossible, owing to the many obstacles that had to be met and overcome. The lack of funds, the ridicule and sometimes active opposition of the residents, the unfriendly attitude of health boards and the funny articles in the local papers were only a few of the difficulties that had to be contended with. But, one by one, the different conditions were met and overcome, the subscription became more generous, the ridicule and active opposition ceased and the papers began to treat the matter seriously. The majority of the community was beginning to realize that the work was being done for their benefit.

A severe wind storm on the 11th and 12th of August, 1902, brought large swarms of mosquitoes to Monmouth Beach, and it seemed for a time to have a very discouraging effect upon the residents who had contributed. This was the opportunity that the cranks had been waiting for, and you can rest assured that they made the most of the opportunity. They certainly tried to make life miserable for the writer, and the papers were not at all backward with their ridicule and funny stories. This was a most trying time for those that were interested in the movement. Prompt action was necessary, consequently bulletin No. 2 was issued, containing a complete statement of what had been done, the amount of oil that had been used, where it had been placed, and the number of men that were in the field. It also stated that the cause of the trouble was due to the high winds, which carried the mosquitoes to Monmouth Beach from places that had not been treated. At the same time maps were being prepared showing the breeding spots and indicating where a little digging to connect pools with drainage points and a little filling in would permanently abate the nuisance. Little by little the way was being prepared for the work that was to follow. An appeal was also made for more funds to continue the work early the following spring. It was also urged upon the property-holders for each individual to become a committee unto himself by looking after his own property, thereby co-operating with the committee who had the work in charge. It was shown very plainly that the results from such co-operation would tend to convince the unbelievers.

August 15th, 1902, the treasurer had received three hundred and eighty dollars ($380) in response to the first circular; another circular was issued stating that the committee had secured the co-operation of the health boards, including Long Branch, Seabright and Ocean township, and the committee felt assured that the work would be successful with the above co-operation. The warfare continued with unvarying success until October, when the committee decided to cease operation until the following spring.

Early in the summer of 1903 the writer issued a special bulletin to the subscribers of the mosquito fund, and copies of the same were mailed to the property-owners from North Long Branch to Seabright. The bulletin contained a complete description of the work from July 12th, 1902. Extracts from the same are as follows: When larvæ are found, oil is placed upon the same, exterminating them almost instantly. The funds have been exhausted; we must have the money to carry on the warfare, and the subscription should be mailed promptly. Oil is not a permanent remedy. Eliminating the pest places is the only permanent relief. This can be done by ditching, draining, and filling in. Oil is necessary in places where the remedy for the disease cannot be reached by a permanent method. It seems to be a prevalent idea that the meadows are responsible for the whole mosquito tribe. The impression is erroneous. The *Culex sollicitans*, or salt marsh mosquitoes, are bred in large numbers and require careful attention, yet there are millions of the pests bred around the houses when the conditions are favorable.

Figure 131.
An excellent gang in a soft place. Shows the kinds of spades used. (Original.)

In order to enlarge his sphere of action, the writer was appointed Assistant Sanitary Inspector of Ocean township, without salary. The appointment was productive of good results, as larvæ were discovered and exterminated in all sorts of places, and many infractions of the sanitary laws were amended. Received seven hundred and fifty-five dollars and twenty-six cents ($755.26) from the subscribers from July, 1902, to June, 1903.

In addition to the report from which the above extracts have been taken, Professor John B. Smith's report approved, based upon the examination of the infected territory by Mr. H. H. Brehme, his assistant, and from his own personal observation. The Professor endorses the work that has been done and fully concurs with the plan for the future propagation of the crusade. Up to the present writing the committee has received every courtesy and valuable assistance from the above-named gentleman and his assistant.

On March 24th, 1902, the work was continued. Two experienced men were engaged on the above date, and seven and one-half barrels of oil had been consumed to June of the same year. The territory had been extended and all the infected places were carefully watched. In addition to the above, three miles of ditching had been completed and many breeding places filled in. The results were satisfactory: temporary results, it is true; but it required the hardest kind of work and the utmost vigilance to obtain the relief from the nuisance that the subscribers demanded. But the time was almost at hand when permanent relief could be guaranteed. The majority of the residents of Monmouth Beach seemed to realize that the joking stage had passed and that the time for concerted action had arrived. It would be just as well to state that five hundred and twenty-two dollars and seventy-two cents ($522.72) were expended in the year 1902. The season of 1903 opened with a balance in the treasury of two hundred and thirty-two dollars and fifty-four cents ($232.54). In addition to this amount, four hundred and twenty-five dollars were subscribed in the summer of 1903, making a total of six hundred and fifty-seven dollars and fifty-four cents ($657.54) to propagate the work. The above amount was not expended until February, 1904. A total amount of $1,770.26 expended in three years, and nothing to show for the same! A very unsatisfactory ending of an arduous and difficult campaign. But better times were coming when the permanent method of eradicating the pests was to be given a fair trial.

In the year 1903 the Rumson Neck Mosquito Extermination Association was formed. The Shrewsbury river divides Monmouth Beach from Rumson Neck. The latter community were aroused to the necessity of commencing a crusade of their own against the mosquito pests. They were awakened to the fact that something had to be done at once. The writer was notified and agreed to help them in their difficulty. The committee of Rumson Neck deserve great credit for the way they took hold of the work. Circulars were issued, one after the other, calling on the residents for financial aid. The responses were liberal, the warfare was on, and continued throughout the entire season. For the money expended the success of the work was doubtful. The work was started too late in the season and there were too many breeding places adjacent to their own territory, that were not treated, to draw a supply from. But the committee were in no wise discouraged and determined to adopt the permanent method the following year.

The writer succeeded in obtaining the post of Assistant Sanitary Inspector of Shrewsbury Township, and was able thereby to be of some assistance to the association. Amount expended on Rumson Neck for the year of 1903, five hundred and thirty-seven dollars and twenty-two cents ($537.22). The committee were very active during the entire season and did excellent work. Numerous meetings were held, circulars were mailed, and the local papers pressed into the service. The matter was agitated continually and kept before the public. A trifle over twenty-three hundred dollars ($2,300) had been spent up to this time on both sides of the river.

In the fall of 1903 a meeting of the residents and property owners of Monmouth Beach was held in the Monmouth Beach Country Club. The attendance was beyond expectation, intense interest in the matter having been

aroused. The object of the meeting was stated, officers were elected and a permanent organization, called the Monmouth Beach Protective Association, sprang into existence. After appointing the various committees the meeting adjourned. The members of the Executive Committee were determined to use every means in their power to destroy the breeding places in Monmouth Beach and vicinity, consequently they were very active during the past winter in marshaling their forces and getting ready for a very active campaign.

Operations were commenced February 15th of the present year. Prof. Smith's assistant, Mr. H. H. Brehme, and the writer covered the entire territory where breeding places were likely to occur and laid out a system of ditches, aggregating in all about two hundred thousand feet (200,000 feet), and extending from North Long Branch to Seabright and from Seabright to Little Silver creek, in the Rumson Neck side of the river. Maps were prepared and submitted to Prof. John B. Smith and the committees of the two associations, a civil engineer, sent by Professor Smith, also submitted a report after an investigation of the proposed system. Said report was very favorable. Upon the completion of the preparatory work the association at Monmouth Beach awarded the contract for the ditching to Mr. Jesse P. Manahan. The ditches were to be six inches wide and two feet deep on the average and the entire work was to be subject to the approval of Professor Smith, or his assistant. Cost of the same about fifteen hundred dollars ($1,500). The work commenced March 24th and was completed April 18th. It might prove interesting to state that larvæ were found in large numbers on March 23d on both sides of the river.

While the above work was going on the association at Rumson Neck determined to adopt the same course of procedure. Consequently, Mr. Manahan was awarded the contract and agreed, for twelve hundred dollars ($1,200), to eliminate all breeding places on the Rumson Neck side of the river. The work was commenced on April 19th and completed May 7th, Professor Smith's assistant, Mr. H. H. Brehme, supervising the same. Upon the completion of the entire system of ditching, the work was pronounced satisfactory and approved as per contract. Baker's field was also drained for two hundred and sixty dollars ($260).

On March 30th the Duffield bill became a law, and on July 11th the Township Committee of Ocean passed an ordinance condemning all breeding places.

The committees of the associations realizing the necessity of keeping the ditches in operation, engaged men for that purpose, and they have been kept in the field to the present writing. The work was a success and the results obtained have been satisfactory. The residents of Monmouth Beach have not been troubled with the pest this year. Mosquitoless Monmouth is the appellation now used; health and comfort have been obtained at a very small cost, considering the benefit derived. The advance in real estate and the increased number of rentals, caused by the absence of the mosquito, will surely be an argument that none can combat. I understand that the associations intend to enlarge their territory and eradicate the balance of the breeding places that still remain a menace to the residents of Monmouth Beach and Rumson Neck. (Signed) EUGENE WINSHIP.

September 29th, 1904.

Mr. Brehme's Report on the Shrewsbury River area is as follows:

During inspections made in 1903 from Seabright to North Long Branch, the following breeding places were discovered: Opposite the Low Moor Station, a small area. A very bad breeding place opposite the United States life saving station between Low Moor and Gallilee. Still a worse place was found

directly opposite the Gallilee Station of the seashore branch of the Central Railroad of New Jersey. This meadow is very low, with many pools, and larvæ had even a better chance to come to maturity than at either of the previous places.

The next point was on the Monmouth Beach golf grounds. On this place a few ditches had been cut before the inspection and it was in better condition than the other points examined. Outlets had been made for the surface water and all the places where larvæ could hatch were dry.

The next place was a large strip of marsh land next to the golf grounds and one-half mile west of the Monmouth Beach station. This is Raccoon Island, the home for mosquitoes, and an ideal breeding ground. There were hundreds of pools and everywhere larvæ were present in uncountable numbers.

The next area looked over was from Pleasure Bay Road southeast to Atlantic Avenue, North Long Branch, and breeding was found everywhere over the whole strip. Inspections were also made up Pleasure Bay to Branchport; but not much breeding was found there, as the high ground runs close to the stream and drains off. Low places are filled with fish, which make mosquito development impossible. From Pleasure Bay Park to East Long Branch are a few bad places on the northeast side of Trautman's Creek. On the west side of Pleasure Bay, called Port-au-Peck, is a long and very bad strip of meadow land which runs up to the Newbolt woods. Blackberry Creek runs through this meadow, and as the ground is low the creek frequently overflows its banks and fills the breeding pools, of which there are between 1500 and 2000 on the meadow. Parts of the meadow are higher and there the pools fill only at extra high tides from the Shrewsbury River or by heavy rains.

The next breeding area is on Foster's Creek, above the New York and Long Branch Railroad, but this is not bad and could be easily made safe. A similar but worse place is on Parker's Creek, also above the railroad, and this also requires but a little work to effect a cure.

The area on Town Neck Creek was twice visited and found in good condition, without obvious breeding pools, hence it is to be considered safe.

The next place of inspection was on the north side of Little Silver Creek. A large piece of meadow lies here, called Kemp's or Great Meadow, and this is the worst piece of marsh land on the Rumson side of the Shrewsbury River. It is to that side what Raccoon Island is to the other: numerous holes of all sizes and all of them developing uncountable numbers of mosquitoes. Every piece of meadow land on the west side of the river to Sea-

bright bridge has been examined and breeding pools were found on all; but from Seabright bridge to Red Bank no such places were discovered.

There are a number of islands in the Shrewsbury River and some of these were found to have bad breeding places.

The results obtained from these inspections were encouraging, and a drainage plan was laid before the people of Monmouth Beach and Rumson Neck.

On February 15th another series of inspections was made to get an estimate of how many feet of ditching it would require to drain the entire strip of meadow on both sides of the Shrewsbury River. After going over the ground carefully, it was estimated that 250,000 feet of ditching would clean the entire meadow from Seabright to East Long Branch, from Pleasure Bay to Little Silver Creek, and from Little Silver Creek to Seabright bridge on the west side.

The Monmouth Beach Association took the matter up at once and secured the money to have the area from Seabright to Atlantic Avenue, North Long Branch, made safe. A contract was given out and work started in March. The pools were then already filled with larvæ, but their growth was slow, due to the cold weather. The work proceeded so fast that before the larvæ were half grown every pool between Seabright and North Long Branch was laid dry. This work destroyed the first brood, which, had it come to maturity, would have swamped Monmouth Beach as this same brood swamped other shore places, including Newark and Elizabeth. Not one of these mosquitoes hatched to do any damage.

The effect of the work was too obvious and the success so great that the residents of Rumson Neck took up the matter at once and gave out a contract to drain the meadow from Seabright bridge to Little Silver Creek bridge. The larvæ were now a little more than half grown and fear was expressed that this brood would get through all right before the ditching could be completed. But a cold spell came in which kept the larvæ back so far that when every ditch was cut but one they changed to pupæ, and one other day would have seen them on the wing. This last lot of the enormous brood was hurriedly drained into the Shrewsbury River, where the killies were waiting for them in numbers sufficient to wipe them all out. The race was won.

This entire work of nearly 200,000 feet of ditching was done for a little more than $2,000. The islands in the Shrewsbury were taken up immediately after the Rumson Neck side was done, and it took only two or three days to make them safe.

Figure 132.
Mr. Brehme and Mr. Winship laying out work for the ditchers. (Original.)

The ditched areas are kept clean by two men employed by the Rumson Neck people and two men on the Monmouth Beach side. The ditches are thus kept in good running order and no breeding places can now exist there.

The area from North Long Branch to East Long Branch on Troutman's Creek and the Port-au-Peck to the south side of Little Silver Creek has not been drained. But this place will in all probability be attended to next spring. Seven to eight hundred dollars will clean out the entire strip.

The breeding places on private property have also been attended to, and while mosquitoes have been all but unbearable in most coast towns in New Jersey, Monmouth Beach and Rumson Neck did not have more than an occasional specimen, which usually came from an outside breeding place!

Mr. Brehme's last statement should be held to apply to marsh mosquitoes only, because it is almost certain that at several points a brood of the house mosquitoes "got away." No mention is made by either Mr. Winship or Mr. Brehme of the fact that some individual owners did considerable work on their own premises. A notable instance is that of Mr. William E. Strong, who owns a considerable stretch of marsh land which was excellent mosquito breeding ground to the extent of millions of specimens. He has ditched and filled this danger area so completely that it is doubtful whether anywhere on his estate a single mosquito can develop.

In explanation of the employment of men to keep the ditches open, it should be said that the shifting sands of the Shrewsbury tend to fill or seal the ditch outlets, and with almost every extra high or storm tide little pools become obvious, which may, under especially favorable conditions, become breeding places.

In closing this account, the circular letter already referred to and a memorandum of others received from representatives of both associations are attached.

MOSQUITO EXTERMINATION.

To all Householders:

The residents of Rumson Neck and Monmouth Beach, through committees, have begun a crusade against the pest of mosquitoes, and for several months have been actively at work ditching and filling in low spots on both shores of Pleasure Bay, under the direction and supervision of Prof. John B. Smith, of New Brunswick, State Entomologist. So far as this work is concerned, it has been so well and carefully done as to destroy the breeding grounds, but it is necessary to have the co-operation of every property-owner and householder of both sides of Rumson Neck, from the Seabright bridge to Red Bank, including Little Silver, and from the village of Seabright to North Long Branch and beyond on the shore, and inland from

Monmouth Beach to Branchport, and incidentally this appeal is intended for the entire townships of Shrewsbury and Ocean.

The co-operation is for each and every householder and property-owner to fill in all low spots where water would become stagnant, to do away with all barrels and cans of any kind holding water, as these are particularly objectionable as places for deposit of larvæ and for breeding of mosquitoes. Further, that where the area is too large for filling in of low spots that ditches be dug of not more than eight inches and of such depth as to carry off the water and dispose of it in such manner as to remove the possibility of breeding grounds. With co-operation such as suggested the comfort and health of the community-at-large will be greatly benefited, as it has been definitely settled that mosquitoes are carriers of disease, and the value of property will be much enhanced. There has been 150,000 lineal feet of ditching on the shores of Rumson Neck and Monmouth Beach, besides filling in of low places, and it is supplemental to this that prompts this appeal by the chairman of the committees of Rumson Neck and Monmouth Beach, respectively, Messrs. William A. Street and Henry L. Thornell.

June 10th, 1904.

* * * *

New York, September 22d, 1904.

Prof. John B. Smith, New Brunswick:

Dear Sir—I am to-day in receipt of your esteemed favor of 21st instant, and have pleasure in saying that the work which was done on Rumson Neck last spring has proved satisfactory, and it has been supplemented by the employment of labor to keep open the ditches and fill in low spots which may have been overlooked, as a result of which we have been practically free from mosquitoes, excepting very occasionally, and the source discovered, and altogether we may all congratulate ourselves on the satisfactory progress and result of our labors.

I only speak of Rumson Neck, but have understood that conditions at Monmouth Beach are similar, although, perhaps, the problem there has been a little more difficult to solve than in our case, but you can obtain more definite particulars through Messrs. Thornell and Stimpson, who had the work in charge, and with sentiments of esteem and confidence, I remain, dear sir, Yours very truly,

(Signed) WILLIAM A. STREET.

* * *

New York, September 22d, 1904.

Prof. John B. Smith, Rutgers College, New Brunswick, N. J.:

Dear Sir—In reply to your letter of September 21st, just received:

It would certainly seem that in weather of this kind mosquitoes would not readily develop to maturity, but examination of some of the infested spots near Monmouth Beach discloses large numbers of larvæ. Our association is satisfied that the draining of the region done under your superintendence last spring was the immediate cause of our comparative freedom from the pest during the summer just past. While this immunity may have been in part attributable to climatic conditions, we are not able to satisfactorily determine just what the favorable conditions were. Like conditions in other years have been attended with rapid progress and development, so that our temptation is to conclude that relief is entirely attributed to the remedies which have been applied. The work done by the association was not properly seconded and supported by the efforts of individual property-holders, but we trust that coercive measures will next year remedy this defect. We are convinced that the proper maintenance of the drainage system will, in our region, require the services of a number of men constantly employed in that work. This necessity is, in large part, due to the entrance of seaweed into such ditches as open into the Shrewsbury river. We shall further extend the system during the coming winter and spring in order that we may obtain complete drainage. Very truly yours,

(Signed) F. J. STIMSON,
Secretary.
(Monmouth Beach Protective Association.)

The infested spots above referred to are on the upland and along the railroad, the meadows, except at Port-au-Peck, being found entirely free from larvæ on September 27th, by Mr. Brehme.

SEABRIGHT, New Jersey, October 4th, 1904.

Prf. John B. Smith:

DEAR SIR—Your favor of of 1st instant has been received. It gives me great pleasure to state to you the result of the work done on Rumson Neck during the season of 1904, and its effect upon mosquito breeding. Fortunately, I have been able to give personal attention to this work, and have become much intrested in it.

The ditching done by Manahan in the early spring, covering the territory from Kemp's estate to Seabright bridge, brought successful results; but was by no means thorough; that is to say, many breeding pools were left untouched, and more or less breeding was going on in consequence. We were fortunate at this juncture in securing the services of W. A. Duryea, and have, by constant vigilance and hard work, destroyed every breeding place in this region. This I can vouch for as the result of personal inspection. It would seem a logical conclusion that if mosquitoes do not breed, they do not exist; certainly, they have been very scarce here this summer at any time, but for the past two months practically none have been in evidence.

We propose to continue the work next year and extend our borders, if necessary, to provide against migration of the pest, which, however, does not appear to have gone on to any great extent this year.

Permit me to say that the residents of Rumson Neck owe you a debt of gratitude for having last year called their attention to the possibility of exterminating the mosquito and starting and directing the work that has practically achieved that result.

With kind regards, I am,

Very truly yours,

(Signed) WM. E. STRONG.

The breeding places left by the contractor and referred to in the previous letter are those small depressions which are not always filled and readily escape detection until just the right combination of weather and tide supplies them with water. It is probably true that after a marsh has been drained by systematic ditching there will always remain a few holes that, because of some local peculiarity, do not dry out as readily as the rest of the territory and, to obtain a perfect result, these must be watched and filled as they develop.

CHAPTER VI.

OTHER SHORE POINTS.

a. THE RARITAN RIVER PROBLEM.

New Brunswick is on the Raritan River about ten miles from its mouth if the windings of the river be followed, not over eight miles in a direct line. There are no salt marshes within the limits of New Brunswick, yet the only seriously troublesome mosquitoes are the salt marsh species. There are plenty of breeding places for *C. pipiens* within the city limits and some where *C. sylvestris* and *Anopheles* breed; but for a comparatively small outlay, aided by the powers vested in the local Boards of Health, the city could be practically and permanently cleared of mosquitoes were it not for the periodical irruption of the salt water forms.

Naturally enough my first investigations were made near my home city and I determined positively, after carefully surveying both sides of the river to the city limits east and to Bound Brook to the northwest, that the Raritan River was not in fault in that stretch. While there are some breeding places along its banks, especially on the east side, none of the species are migrants and, so far as New Brunswick is concerned, they might just as well be non-existent. These preliminary surveys were made by Mr. Dickerson and myself before we had learnt much about the habits of the salt marsh species. Afterward I sent Mr. Grossbeck down the river with instructions to locate the breeding places along its course. The river banks are high for some little distance below the city and it is not until the vicinity of Sayreville is reached, that the typical salt marsh begins to form the banks. And as soon as that formation occurs, breeding places for the salt marsh forms are found. These Raritan River meadows have been kept under constant observation for two years and almost every brood has been noted and watched for at New Brunswick. The cities of South Amboy and Perth Amboy, situated at the river mouth, naturally get the heavy end of the supply and a large proportion of the breeding area lies within their limits; but enough specimens are left over to supply Metuchen, Stelton, New Brunswick, Milltown and all intervening points, with sometimes an excess that extends to Bound Brook, Dunellen and even Plainfield.

Mr. Grossbeck's survey gave an outline of the general breeding area and the question arose whether there could be any re-

Figure 133.

Filling deep pools with sods cut from ditches: the holes pointed out by Mr. Brehme. (Original.)

inforcement of the supply from other points. Mr. Brehme's explorations, aided by those of Mr. Grossbeck, show that along the Arthur Kill there is very little salt marsh just north of Perth Amboy, and that the Staten Island shore just opposite is also highland and not dangerous as a mosquito supply. To the southeast the shores are good except for a small area near Morgan and, as a whole, the population along the banks of the Raritan derives its mosquito supply from the salt marsh area within five miles of its mouth. There are few territories so favorably located for practical work and to determine what was needed I assigned Messrs. Wagner and Mellor to make a careful survey of the breeding area with the view of determining what work was necessary to make it safe. They were given the marked maps prepared by Mr. Grossbeck, but were instructed to extend it as needed if it seemed in any way incomplete. During their survey the marshes were flooded by storm and tide, and one of the heaviest broods of recent years developed; so it is fair to suppose that they found the limit. At all events no more recent examinations have extended it.

The reports presented are brief and to the point. They are given herewith with the maps which show what ditching is required.

At a liberal estimate the marsh work, assuming that the ditching machine can be secured for use, should not exceed $5,000. As the benefits will be shared by a population exceeding 50,000, the outlay seems small, divided as it should be, between New Brunswick, Perth and South Amboy, Metuchen and the minor intervening towns that would be improved by the work.

Report on South and Perth Amboy.

In the map of this territory which we submit we have embodied our suggestions as to what might be done towards doing away with mosquito-breeding. Those places which we found good we have left unmarked. Those which we found bad we recommended for ditching, where ditching was possible. The ditches we have drawn in red ink. The length of each one is stated, its direction indicated, and its position with reference to some given point, so that, with the aid of the map, whatever we had in mind can be followed without difficulty. It remains to state the reasons for our suggestions:

(1) In the territory marked (A), between the Central railroad bridge and the new Amboy bridge, there are a number of individual depressions in the soil, some near the river front, others farther back. Rain collects here, and the overflow from very high tides. In each case we have drawn ditches straight to the river. These will give rain-water a chance to flow off, and also water from high tides an opportunity to get back.

(2) In territory (B) the depression is more general. Heavy rains form a large amount of surface water. We have drawn ditches to lead this into the creek shown on the map. We have also noted that two old ditches (shown on the map) be connected and given a better flow.

(3) Territory (C). The land here is good for 600 feet in from the north of the river and for 200 feet in from the west. Then it becomes bad, forming a kind of basin. We have drawn a main ditch through the middle of it from the river to the creek. On either side ditches 60 feet apart are drawn. The necessity for having them 60 feet apart is this: there is not much surface water. There is a vast network of holes filled with water, and to drain these it is necessary that the ditches be close together. In this place we found the greatest breeding.

(4) Territory (D). There is a spot of high ground here. But in places where ditches are drawn are depressions, which we found prolific breeders.

(5) Territory (E). Here there are a number of low places, in from the shore, where breeding goes on. The trouble here, as in the rest of the places, is that between the low places and the shore the land rises, making it impossible for the water to get to the river. The land rises only a very little, but enough to keep the water back. Ditches cut to the river would lead the water off.

(6) Passing to the Perth Amboy side of the Raritan river, we come to two low places between Weber's brick works and the National Fire-Proofing Company's works, about which the map tells all that is necessary.

(7) Territory (F). Here we have drawn a main ditch through the middle of the bad territory, with ditches on either side.

(8) Territory (G). We have done the same with (G) and with (F), varying the length of the side ditches according to the extent of the bad area. In both (F) and (G) we have not made the side ditches close together, because the territory is not very bad.

(9) Territory (H). We have drawn a main ditch to lead the water into the creek, and where the area is bad have placed side ditches, varying in length. The land here is, like (C), a network of holes, in which great breeding goes on.

(10) Territory (I) is not as bad as (H), and less close ditching will suffice.

(11) Territory (K) is a comparatively small portion of bad area.

(12) Territory (J). Here the character of the ground varies. Some parts have surface water, others are a network of holes, and some places are good. But in general the territory is very bad, and only straight ditching into the creek will suffice.

(13) Territory (L) has the same character as (J). Surface water is a little more in abundance.

(14) Territory (M) has a number of depressed places about 15 feet in diameter which are breeders.

(15) The soil. The soil on both sides of the river, the South and the Perth Amboy sides, is the uniform marsh soil, covered with various kinds of grass and with cat-tail growth. It will easily maintain a ditch.

(16) Along the eastern side of the point or headland, about 50 feet in from the shore, are a number of salt holes. They are deep. Fish get in them and no breeding goes on.

CHARLES WAGNER.
JOHN MELLOR.

Report on the Vicinity of Sayreville.

(1) On the Sayreville side of the river the ground is generally good, being used for haying purposes. But in places A and B there are groups of holes, mostly small, many being only one foot in diameter, and these are breeders.

(2) Passing on to the other side of the river, at territory C the breeding is large and confined to small depressions, making ditches at intervals of 60 feet necessary.

(3) On this side of the river there is a general submergence of the land, and breeding goes on. On the right of the clay railroad the land is good for 400 feet in from the shore. Here we have drawn a long ditch intercepting the parallel ditches, with every fifth ditch running into the river. Besides the prevalence of surface water, there are also groups of holes in which breeding

goes on. Every part of the territory that we have marked is not bad. There are some places where there is no breeding. But the whole territory is so bad in general that only a comprehensive scheme of straight ditching will suffice. As most of the water is surface water, there not being many holes, close ditching is not necessary to drain, and we have therefore mapped the ditches 120 feet apart.

(4) In territory D the situation is different. Here there is practically no surface water. Breeding goes on in holes that vary from one to fifteen feet in diameter. Outside of the holes the ground is dry and solid. In order to be certain that every hole will be drained, the ditches must be close enough to drain all intervening territory. We have therefore mapped ditches 60 feet apart.

(5) The soil here is of the same nature as that of the South and Perth Amboy territory.

CHARLES WAGNER,
JOHN MELLOR.

b. THE RAHWAY PROBLEM.

This practically includes the territory from Morse's Creek to Carteret and along the Kill to the beginning of the Amboy territory. It was covered in part, along the Rahway River, by Mr. E. Brehme in 1903; Mr. H. H. Brehme went over the marsh section between Morse's Creek and the Rahway River in 1903 and 1904, and in the latter year also covered the river marshes. Mr. Grossbeck explored the stretch between the Rahway River and Perth Amboy. The following account combines the various reports made.

The meadow south of Morse's Creek is high and solid, and there are few holes in it. Almost the entire stretch to Tremley Point is used for growing salt hay which is cut by machine, the horses not even requiring meadow-shoes to prevent them from sinking or cutting into the sod.

Nevertheless, mosquitoes breed on these meadows in considerable numbers; but the bad places are all close to the highlands and often in choked up ditches where fish cannot enter. There are several ditches close to the highland and if these were cleaned out to Morse's Creek they would be sufficient to take the narrow ditches necessary to drain the breeding places. These ditches would not have to be very long nor very numerous and they would carry the killies that simply swarm in the creek to the low breeding pools that might not be completely drained; live water with fish would be substituted for stagnant pools with wrigglers.

A similar condition of affairs exists on the east side of the New York and Long Branch Railroad. There are plenty of developing mosquitoes, but most of the places are found close to the high ground. Here also there are a number of old ditches choked with grass and weeds, useless for purposes of drainage:

but excellent for preventing the entrance of fish to the pools. The same measures recommended above apply here.

There are a few low places opposite Buckwheat Island which are best drained by ditches into the Arthur Kill. All the others, near the highlands, can be led into the creeks which branch in every direction, which are filled with fish and which are so located as to make the complete drying out of the meadow the simplest sort of a task.

The area south of Tremley to the Rahway River on the east side of the New York and Long Branch Railroad has a number of very bad breeding places which produce great numbers of specimens at all periods during the summer. There is little natural drainage here and in the absence of creeks or other water courses several wide ditches would have to be cut here to receive the narrow laterals that would reach into the low places. This would form the most expensive section and would at the same time put out of existence the worst breeding territory in this vicinity.

On the west side of the New York and Long Branch Railroad, from Tremley to a high piece of ground near the Rahway River there is another very bad breeding place. The meadow is not large and it lies high; but the holes in it are not supplied with fish in any case so that all of them are mosquito factories. It needs only a few short ditches to reach all the dangerous holes and drain them.

The area on the south side of the Rahway River from the New York and Long Branch Railroad to the Arthur Kill east and west and the highland on the south has a considerable number of bad breeding pools. This is a rather solid meadow; solid enough to bear horses, and a considerable portion of the salt hay is cut with mowing machines. A number of natural creeks and some ditches run through this meadow. The ditches can be made more useful by cleaning them; the creeks are in better condition and can be used to receive the narrow drainage ditches. Ditches will not be needed in many parts of this meadow as it contains comparatively few holes; a much smaller number than is found in those further north. The ground is good and ditches once cut will stand indefinitely with only a little care to prevent their being clogged. The Rahway River is deep enough to give the ditches a three-foot fall, enabling them to completely dry out the low area close to the highland. This is one of the most easily drained marsh areas in New Jersey and good results should be obtained here with less money than any other equal section of the territory in the State.

The area further south, toward Carteret, is in about the same general condition as that above mentioned, though not so easily dealt with. There are a great many holes in this meadow which breed myriads of mosquitoes and yet 40 per cent. of all the holes on it contain fish and are safe. Some of these larger pools are deep enough to hold water and maintain the killies during even long droughts; but some of them dry up easily and when, after the death of the fish they become refilled by rains, they make enormous contributions to the general mosquito output. There is practically no natural drainage on this marsh and large ditches, two and one-half feet wide and three feet deep, would have to be cut into the Arthur Kill to receive the necessary narrow drains. The land is solid enough to maintain ditches indefinitely and the banks of the Kill are bold enough to take the wide ditches effectively. Both hand and machine work could be profitably used on this meadow. The ground is in such condition that the machine could cut both six and twelve inch ditches easily, and only a few places would be better done by hand labor.

The territory on both sides of the Rahway River west of the New York and Long Branch Ralroad is not very dangerous. The meadow is not very wide and contains very few bad breeding holes; the south side more than the north; but neither is very bad. Hand ditching is indicated here, because only short ditches are needed and the Rahway needs three-foot outlets to drain the area perfectly. The river carries killies in great numbers and these would penetrate to the very head of every ditch, taking care of every larva that was drained into it.

The territory between the Rahway River and Perth Amboy was surveyed from the latter point and the report reads, therefore, from the south instead of from the north as in the others.

The salt marsh extending from Perth Amboy to the mouth of Woodbridge Creek, bordering the Arthur Kill, breeds few mosquitoes, comparatively speaking. The area is mainly overgrown with reeds and is almost constantly covered with water. There are depressions along the highlands, however, that retain water after the recedence of high tides and these become dangerous and need attention. All of these can be easily drained into already existent ditches.

Along either side of Woodbridge Creek the marsh area is prolific breeding ground. Almost all parts of the marsh are mown for salt hay and shallow pools are scattered over the whole territory. Close to the creek and along some of the larger ditches which cut this meadow there is a broad area of safe ground and such large pools as occur are filled with fish. A short distance

beyond Colwell Avenue, which crosses the meadow, there are no more depressions and no breeding can occur.

From Sewaren northward to the Rahway River, the meadow bordering the Arthur Kill breeds mosquitoes in almost all its parts, though not very abundantly anywhere. The marsh is well drained by creeks and ditches and close to these no mosquitoes breed. The pools are not numerous and reed grass covers a large part; which indicates a usual covering of water. Many of the pools are crowded with fish, as are also the reed-covered patches. Breeding may occur, to some extent between the reeds, in open spaces, when most of the water has evaporated.

Altogether Rahway has perhaps the cheapest and easiest task of the larger cities owning or adjacent to salt marshes.

CHAPTER VII.

REPORT ON INVESTIGATIONS MADE ALONG DELAWARE BAY FROM SALEM CREEK TO DENNIS CREEK.

It was impossible during the season of 1903 to cover any of the area along the Delaware River and Bay in a systematic manner. From personal visits to various points along the river and in the interior, and from the reports of correspondents, I felt quite certain that no breeding places existed north of Salem. At that point the river banks are high, the fresh water dominates, and there are no salt marshes. Alloways Creek may, perhaps, be fixed as the northern limit of true salt marsh area along the New Jersey shore of the Delaware, and, of course, this also limits the breeding of the marsh mosquitoes.

A large number of creeks extend inland from the bay shore, some scarcely reaching the highland, others of considerable size coming from the east side of the elevated ridge that runs roughly parallel with the Delaware and at some distance back. This is joined north of Clayton by a ridge running northwest from the Cape May peninsula, forming a basin from which the Maurice River carries most of the water, with the Cohansey Creek forming a good second. The marsh mosquitoes dominate this entire territory and are often excessively abundant not far from the

shore, but for some reason they do not fly so far inland from these Delaware Bay marshes; and with mosquitoes in swarms at Greenwich and along the bay, Bridgeton may be practically free, though Bridgeton gets its share at times. An important question was, how far up these rivers and creeks do danger conditions extend and is there any breeding of salt marsh forms when the creek water has become entirely fresh. A second question, of almost equal importance was, does the marsh along that area have the necessary consistency to maintain a ditch, and if so, what chance of cheap drainage is there.

The exploration of this area was intrusted to Mr. John Mellor, a graduate of the engineering school of the college, who, as an undergradute, had done similar work for me in 1903, with Mr. Wagner. The period between June 16th and July 15th was unusually dry, which was fortunate, because the work was not interrupted; but not so fortunate in that many breeding areas were dry. This made the work more pleasant, but made it necessary for Mr. Mellor to determine the breeding areas from the character of the land rather than from actual observation. In this the experience gained along the Atlantic shore stood him in good stead, and I believe that little remains to be added even in a wet season.

The river and bay shore is sandy for almost the entire distance surveyed and sometimes there is a ridge or bank separating it from the marsh area that begins immediately back of it. Practically all the marsh carries a heavy sod over a mud or clay bottom, all the streams and creeks running through it have well defined edges, and all ditches eighteen inches or more in depth have no vegetable growth in the bottom. Some of the ditches have been in place for years, have the banks heavily fringed with reeds and yet drain perfectly and carry fish freely. All parts of the marsh then, with possible local exceptions, are drainable by means of narrow deep ditches and there is a large number of creeks into which these ditches can be carried. Much of the marsh is used to grow salt hay and some ditching has been done to drain areas for that purpose—always with success. Sometimes this drainage is sufficient to prevent mosquito breeding; more often it is not. Bad places are sometimes intentionally avoided because more ditches would be needed to make it fit for haying.

Accompanying his report Mr. Mellor prepared a map showing the territory explored and with the breeding places marked, but this map cannot well be published herewith.

Mr. Mellor's report is as follows:

Thursday, June 16th, 1904.—I left New Brunswick 8:31 A. M., and arrived Bridgeton 1:30 P M. The afternoon was spent in locating, getting information about the creek and its banks, the tides and the use of a boat, also the collection of adult mosquitoes was made, and these proved to be *Culex cantator,* not a single *sollicitans* being found. The adult has not been numerous in Bridgeton for the past three weeks, but, according to report of residents, there were plenty of them about three weeks before my arrival. All the adults I found were caught while I was walking the reclaimed land on the bank of the Cohansey, south of Bridgeton. I caught about eight (all that got on my clothes). During the evening I went about town and sat on porch of boarding-house, but found mosquitoes scarce.

My first operations were on the west and north bank of the Cohansey. I walked three miles down from Bridgeton along the west bank This is all reclaimed land. There is a high (above extra high tide) bank or dyke along the creek, with sluice gates at intervals of about three-quarters of a mile. These are kept in good repair, and from the condition of the ditches (amount of water being small at high tide) they seem to be serviceable. I found no breeding places, and, consequently, no larvæ on the reclaimed land. There seemed to be plenty of fish in the ditches leading to the sluice gates. The reclaimed land is used for pasturing and grass.

Friday, June 17th.—I took a short (two miles) walk north of Bridgeton. I found the water fresh. The creek is much narrower. Bladderdocks, reed grass and cat-tails were abundant. There is a layer of mud on bed of creek, but the under soil and on banks is sandy. I found neither adults nor larvæ. I saw nothing like a *sollicitans* or *cantator* breeding place. I turned to the territory south of Bridgeton, north and west of the Cohansey. I went on a wheel making stops along the creek at intervals where roads were found. The territory is protected by a bank as far south as Greenwich. To this point no marsh grass was found. Corn fields and pasturing land were found. The ditches had some reed and cat-tails, but were well stocked with fish. The soil was loamy and good farm land. The territory neighboring the reclaimed land and back from the bank of the creek is sandy. The Cohansey is fresh above the vicinity of Greenwich.

Saturday, June 18th.—I rode bicycle to Greenwich. There is a sluice gate in the bank near Molly Wheaton's Run which is out of repair. Along the road at this place, on the territory toward the creek, I got vial No. 1. Here also were found an abundance of adults, which proved to be *sollicitans* mainly, and a few *cantator*. Pushing south to Buena Vista, and going about a mile beyond, nothing was found in the larva state. Adults were abundant as at Greenwich. The bank in the neighborhood of Greenwich was not in good condition, places being found through which an exceptional high tide would pass and cause a break. On June 30th I noticed in passing this point in the launch that the bank was being repaired by the work of Dredge No. 1 of Houston-Rickards Dredging Co., 714 Girard Building, Philadelphia. Pa. On the bank of the creek south of Greenwich there are some breaks in the bank. There are also some places which undoubtedly are breeders, although they were dry at the time I visited them. These explorations were carried on to a point about a mile from Tindall's Island. If the sluice-gate is repaired at Greenwich, and the bank just below the town is rebuilt, the immediate neighborhood on the north bank will be safe.

Monday, June 20th, Tuesday, June 21st.—Explorations along east and south bank of the Cohansey came next. The bank as far south as one mile below Tindall's Landing has steep sandy sides. Then comes three-quarters of a mile (land distance) of salt marsh. This is mostly covered by every high tide. Reed and wild oats are abundant, making a feeding ground for rail birds. There is some salt grass cut. I did not find any breeding area. From this point west there is broken meadow. The bank in several places has given way and the high tide gets in. No breeding places were found until Laning's Wharf is reached. Here is salt marsh covering the point of land making bend in creek. The place was quite dry but some shaded holes had a few larvæ and here vial No. 2 was obtained. Adults were not very

numerous. Those which I caught in tube containing cyanide of potassium were judged to be *sollicitans* and *cantator*. The marsh affords a good hay crop. The sod is thick and the soil clayey and firm. From the appearance of small natural drains (ditches) the use of ditches in this locality is practical. Southwest of Laning's Wharf (farmer by name of Miller at Laning's Wharf) the bank built to keep out high tide has a large break in it. The tide gets in and completely covers the section which is marked "flooded at high tide." Still further down the creek and opposite Buena Vista there is a large area which has many breeding places. This was also very dry, but salt grass had grown long and heavy. The marsh was firm, having a good sod and solid soil. Marsh grass was most abundant, some reed being along the edge of ditches, and there were some patches of three-square grass. Adults were scarce The territory near the mouth of the creek was tramped over at beginning of trip to Salem Creek.

Friday, June 24th.—Explorations were made with a launch near the mouth of the Cohansey, opposite Tindall's Island. Breeding places were found on both sides. The marsh extends to the water's edge, and high tides wash up on edge but not over it. There are some natural drains. Near these and the edge of the Cohansey the marsh is safe and well drained, but in the interior there are some depressions which hold rain-water or water from exceptionally high tides. The sod is heavy and the soil of a clayey nature. Marsh grass in from the shore was thick and long. There were adults about, but the strong wind made it difficult to capture many. Those captured were five *sollicitans,* two *cantator*. This territory yields excellent hay crop—quantity considered. There are patches of three-square grass, usually in wet places. In these wet places no larvæ were found. We got to the mouth of the Cohansey, and, because of the strong wind, we decided to anchor until morning.

Saturday, June 25th.—We started 6 o'clock to survey the marsh at the mouth of the creek. Breeding spots were found on both sides. On the south side of the mouth (Cohansey Light) there are mud holes and pools. The high tides get very close to the level of the marsh, and at exceptionally high tide the marsh is covered so that the Cohansey Light looks as though it were on an island. This I learned from the light-keeper. There is a good heavy sod all through this section and the soil firm. Near the Cohansey sedge is most common and is short. Along the natural drains reed is found, but this does not interfere with the drainage. The reed grows up on the marsh and not in the ditches (where the ditches are eighteen inches to two feet deep, or more), so that at low tide the bare mud bottom of the ditches shows complete and easy passage of the water. High tides flow up into these ditches, but do not reach depressions in the marsh. There is a slight elevation of the edges of the ditches, which keeps the water back at ordinary tides. These ditches (natural) usually afford an outlet for ditching, if such were desired. On the north side of the mouth of the Cohansey there are a large number of pools and mud holes. In the pools (large and small duck ponds) there is an abundance of fish. These were always clear and clean in appearance. No larva was ever found in these during the trip. The mud spots and holes were usually dry and the mud cracked and curled on the surface. The deeper and more shady ones, however, had water and from these vial No. 3 were obtained. Adults were numerous, mostly (90 per cent.) *sollicitans,* in about sixty specimens observed. Near the creek bank and bay shore the marsh growth was sedge, but in the interior marsh grass became predominant. The grass is cut each year, but seemed rather short at the time explored.

The trip north to Salem was decided upon because of the tides. The shore has a sandy edge, with the marsh extending to the bay shore, and the sod is thick and the soil firm. A stop was made at point marked 4 and vial No. 4 was obtained in several neighboring pools. There were plenty of breeding places. The marsh was of same general character as at mouth of Cohansey. Moving up bay shore the sandy bank continues. The next stop was Fishing Creek. The territory north of Fishing Creek has a great

number of bad breeding places. Between Fishing Creek and Jacob's there are a great many salt holes, so that it is difficult to walk without stepping into one and sinking to the knee. The grass is long and covers the top of some of these holes. The sod is thick, but the under soil is soft. Vial No. 5 was taken at place marked (5). The places marked with red ink indicate the territory on which we tramped and found breeding places. While the entire territory could not be tramped in the short space of one month, nevertheless, the landings were numerous enough and the tramping sufficient to get a very good knowledge of the entire territory. The bay shore continues sandy at the water's edge and marshy from point close to shore toward the interior to Stow creek. Stow creek has stiff or hard mud sides, with thick sod growth on marsh on either side. In this creek the difference of high and low tide level is about three feet, and in all the creeks of similar size, as Mad Horse, Hope and Alloways, the same difference holds. This affords excellent drainage and a possibility for complete draining of stagnant places on the marsh. Vial No. 6 was taken from places above Philip's creek as indicated. The sod on the marsh is heavy and the under soil soft. Territory had large number of adults—great number of breeding holes. This had most abundant supply of larvæ yet found. Only the deeper pools had water. The shallower places were dry, or not more than damp. Grass is cut for hay on this part of the marsh. The small, narrow creeks, or natural ditches, hold steep, slant sides and adjacent territory to them is safely drained. The marsh above Philip's creek is called "Three-Mile Marsh."

Sunday, June 26th.—Bay shore continues sandy and marsh begins a short distance inland. Muddy Creek can be entered by boat drawing three and one-half feet of water only at high tide. For one-quarter of a mile back from shore the marsh is hard. Beyond that there are sink-holes, bogs, musk-rat runs and bare mud spots. There are large and small pools, in which there are fish. The sink holes are breeding places and might be well made safe by ditching or connecting with larger pools. The sod is heavy, but marsh soft and under soil soft. The reed grass along creeks get taller the further we go up shore. The character of the shore continues as before to Deep creek. Most of the pools (small) are dry and mud-cracked. Larger pools have water and fish. No larvæ found, but many adults. Only *sollicitans* were observed. The marsh is firm, with good, deep sod and clayey under soil. The character of the shore continues uniform to Mad Horse creek. The water in these creeks, as far as the exploration was carried, is salt at low tide, which is evidence that at high tide salt water is found as far as the marsh extends. A great many small creeks and ditches run into Mad Horse creek. This makes a great part of the neighboring marsh safe. The edges of Mad Horse are safe. They have a thick growth of reed grass and the bank is composed of hard mud. At the place marked (a) there are a great many mud holes, which are breeding places. There are a great many muskrat houses on this marsh. The rat paths were dry, and hence no larvæ were found in them, but I see no reason why these runs should not be breeding places, since they are very irregular and uneven. At (b) the grass looked as though it had not been cut for a season. There was much uncut dead grass about. There were a very few breeding places. At (c) there was a widespread growth of reed on the edge of numerous small ditches or creeks. No breeding places were found. At places marked (d), (e), (f) landings were made. At (d) some breeding places were found in salt grass area. Rat holes, runs and houses were also found. The territory has some natural drains and, with the heavy sod and clayey soil, the bad spots might easily be cared for. At (e) there were a number of bad breeding places near the Delaware bay shore, within fifty feet of shore. They were all in one place and close together. At (f) a few breeding spots were found. The sod is uniformly heavy and the soil firm. Vial No. 7 was obtained at place marked (d). Only the deeper shaded pools had water everything else was dry. There was an abundance of shells in the water, as evidence of the full development and flight of the mosquito, and

many adults were found, all *sollicitans,* without exception. The neighboring small ditches, or creeks, have steep sides, which shows that ditching could be done in this locality. Mad Horse creek has a very strong tide, both ebb and flood.

Monday, June 27th.—At 6 A. M. we left Mad Horse creek. The character of the shore remains unchanged. The sand on the shore is continuous, but the marsh keeps close to the water's edge. We ran to Fishing creek and examined the neighboring marsh, noting places marked a, b, c, as characteristic of the marsh. At (a) there were breeding places. It is located in the centre of the creeks and might easily be treated. The marsh grass was long and thick. The turf solid. At (b) we got specimens of larvæ—vial No. 8. The marsh was dry and like in character as at (a). At (c) many bad spots were found, but all were dry. The sod was thick and soil pasty and heavy. In all this territory the creeks (from Cohansey up) have reeds on the bank. Three-square grass is abundant, but the marsh grass areas are extensive and cut yearly. The character of the shore to Hope creek is as below Fishing creek. The marsh about Hope creek was tramped at places marked (a), (b), (c) and (d). The water in the creek at (a), (b) was salt at low tide. Sunday night, June 26th, a thunder storm caused a half hour's rain, but very little of the water was visible on Monday. The marsh grass in this locality has grown thick and long. At (a) and (b) the marsh is in a good condition, the breeding places being few and in places marked. The sod is thick and soil solid. Few adults were found. At (c) there were a large number of bad holes. Marsh and three-square grass, rat houses and tracks were observed. At (d) there were a few bad spots. Vial No. 8 was obtained in this locality. The character of this part of the marsh is thick turf and firm clayey under soil. The Delaware shore continues uniform as far as Alloways. Off Stony Point the dredging operations in the river were noticed.

We ran up Alloway's creek to Hancock's Bridge. On the left or north was reclaimed land, and cattle feeding. On the left or north side, at the mouth, the reclaiming bank was broken down, but has lately been repaired. The dredge No. 2 of Houston Rickards Dredging Company, Girard Building, Philadelphia, Pa., was at Hancock's Bridge at the time of our visit, taking mud out of the creek and making a bank.

Tuesday, June 28th.—On the south side of the mouth of Alloway's creek there is some marsh, a large area of three-square grass, some breeding places, few adults, no larvæ, and cattle put out to pasture for the entire season were observed. The breeding places were not numerous. The grass was thick and the soil was firm and hard. The territory north of Salem is safe. Numerous creeks and inlets make the area safe. High tide covers the marsh opposite the northern end of Reddy Island, and the marsh at the mouth of Salem creek showed no breeding places.

Wednesday, June 28th, 1904.—We ran back to Stow creek and up Stow creek to point marked (9). A shower Sunday night and rain Tuesday night made the marsh wet in some parts. In some of the places previously noted we got vial No. 9. The young larvæ were found in many pools, though not in great abundance. On the right side (up stream) the holes were most numerous. The marsh was solid and had a good sod. On the left there was better marsh grass (length and thickness). There were a few breeding places. Reed along bank five feet high.

Thursday, June 30th, 1904.—We went south of Cohansey creek as far as Middle Marsh creek. The neighboring marsh is famed for mosquitoes among boatmen. We navigated in a row-boat. The rain of Sunday and Tuesday had filled many places such as were found dry further north. Tube No. 10 was filled on left of mouth of creek (toward Cohansey). There were a large number of breeding places, few adults *(sollicitans)*. The marsh has a heavy sod and the under soil is firm. The marsh affords a hay crop, but the breeding places cut up the marsh considerably. Sedge grows near bay shore, and this part of marsh (200 feet back) is safe. There are numerous creeks. The breeding area lies in a sort of basin in the center. The territory within 150 feet of creeks is safe.

Friday, July 1st, 1904.—We returned to Bridgeton.

Tuesday, July 5th.—The territory from Middle Marsh to Back creek is similar in character to that about Middle Marsh. There are more duck-ponds, and in places the under-soil is not as solid. There are numerous breeding places, as indicated. We reached Back creek at 5:30 P. M., just as a thunderstorm was getting up in the northwest. We anchored at the mouth of Back creek and walked to the west as far as point marked (2). Everything but largest pools was dry. Only three adults noticed in a mile walk. Elder bushes, marsh grass and sedge was the growth. There were no larvæ, but plenty of breeding places. Marsh grass was very short. Marsh safe along ditches. Heavy sod and firm under-soil. We returned to the boat just in time to avoid rain, which fell for half an hour.

Wednesday, July 6th.—We went up Back creek. The same territorial conditions exist. The larger pools had a little more water, but the mud-spot and smaller places were only damp. The large pools had perpendicular sides, showing the character of the marsh with respect to probability of the ditching holding sides. Tweed creek runs almost dry at low water. Landings were made at the cross ditches and all four sides examined. The character of the marsh does not change. No larvæ were found. The marsh neighboring the Drum Bed was next visited. Marsh grass was longer, the turf thick, soil clayey, plenty of breeding area was found. Very few adults. From this point south rat houses and runs were not found. In this locality there were some pools (small) shaded by grass, from which vial No. 11 was obtained. In most of these pools shells of larvæ were found. The bay shore to Cedar creek has the same kind of sand along water's edge and marsh bordering shore, as observed, toward the north. Tramping was done in neighborhood of Bower's and Howell's creeks. On right, going up, there were duck-ponds and many breeding places. The marsh was very dry. Dead grass cracked under feet. No larvæ were found. Dead fish were found in pools. The sod is heavy and soil clayey. Water in creek at extreme low tide is brackish, but at flood tide it is salt. On left side of creek marsh is the same.

Thursday, July 7th.—Mantuxent creek comes next. Tramping was done in places indicated by places marked. Larger pools have fish. The smaller ones were dry. *Sollicitans* numerous. No larvæ were found. Mud cracked and in places curled. All through this marsh the sod is thick and soil clayey. These conditions describe the marsh so far as Newport Landing. Low tide prevented further passage up creek. The character of the bay shore to Dyer's, Padgett's, Low and Pigs, Beedon's and Fortesque creeks is sandy at immediate water's edge and marshy within a short distance of shore. The marsh about these creeks has many breeding places between creeks. Between Dyer's and Padgett's, duck-ponds and smaller pools were numerous. There is a great sand bank along the bay shore, probably six to seven feet above marsh level. Exceptionally high tides do not cover this sand bank, but do get on the marsh. There is much breeding area on the marsh straight to Fortesque. The sand bank along shore is high all the way to Fortesque. The sod is thick and soil firm. A great deal of hay is carted from this locality. The road used by the teams becomes a breeding place.. If bushes and the poorest of salt hay were spread along the marsh, with the addition of other available materials, and if ditches were dug on each side of this roadway, the difficulty would be overcome.

Friday, July 8th.—The marsh about Fortesque is very bad. A large part of it is owned by Captain Lehman Garrison, Bridgeton, New Jersey. From Fortesque all the way to Straight creek was one succession of breeding area. We went up Straight creek and tramped about in places indicated by red lines. The sod is always heavy and the under soil generally clayey. There are places, marked by red dots in the lines where soft mud holes, salt holes, are numerous. Adults were found in abundance. Vial No. 12 was obtained at Straight creek. I found larvæ in shaded pools. We anchored in Fishing creek for the night. Water in these creeks is salt.

Saturday, July 9th.—We traversed the full length of Fishing creek, going up with and returning with the tide. We expected to get out into Oranoaken

creek as shown by the map. We got within twenty-five feet of the creek, and found the passage too small for our boat. I walked the entire center of this territory and found it uniformly bad. We had to go around Egg Island Point. The marsh through this section has a good sod covering, but the undersoil is firm at one place and soft in another. Marsh grass is heavy. We found *sollicitans* quite numerous. *Cantator* were found frequently inland. Plenty of larvæ. Vial No. 13 taken in place marked.

Sunday, July 10th.—We rounded Egg Island Point and went up Indian creek. Vial No. 14. The conditions just named hold here also. The locality tramped is indicated on map. The shore to Maurice river has marsh to the water's edge, with some sand, not as a bank, however. We could not land along this shore because the wind was blowing too much. I, therefore, cannot report on this stretch of two and one-half miles. Along the Maurice river nothing was found in the form of breeding area. The tides cover the marsh. Our explorations terminated at East, West and Dennis creeks. We ran up Dennis creek about five miles (water distance). The marsh had a large number of bad breeding areas. In the locality marked with ditches was especially bad. The old ditch was in excellent condition, and most of the new ditching well done. The entire marsh has a good top sod and had firm clayey under soil. The territory in locality of East and West creeks has the same general character. The hay crop was heavy, and no doubt the ditching done there and at Dennis creek was for grass improvement. We returned to Maurice river, and Monday, July 11th, returned to Bridgeton by trolley. I could not have covered so much territory if the owner of the boat had not been more than willing to hurry on the work. His boat was admirably adapted to the purpose, and the engine did not cause many and no long delays. Mr. Edwin Wescoat, 280 South avenue, Bridgeton, the owner, knows a great deal about the marshes over which we passed, and gave much assistance. At Dennis creek the marsh was very dry, and, hence, no larvæ found; some adults were found, but very few. This gives this extent and finding of our investigations.

Respectfully,

July 15th, 1904. JOHN MELLOR.

CHAPTER VIII.

INLAND WORK.

a. THE PROBLEM OF THE ORANGES.

At the base of the first and second ridges of the Orange or Watchung Mountains is a series of towns and villages, extending from Maplewood to Montclair, embracing all the Oranges and a number of other settlements, chiefly to the north and east, that are favored as places of residence by many whose business offices are in Newark and New York. In some of these towns are the magnificent homes of the wealthy and well to do; in others the more humble yet cosy cottages of the clerks and mechanics whose

earnings are sufficient to enable them to get out of the crowded city at the end of the day's work to enjoy the blessings of pure air and nature quiet. There is beauty in all these places and in many others not far off; but the blight of the mosquito pest lies over all. Magnificent dwelling sites find no purchasers because of the necessity for close screening to keep out mosquitoes and because, as soon as darkness sets in, piazzas must be abandoned to escape the annoyance caused by these little nuisances. In almost any car on any morning train to the city during the summer, somebody may be heard talking of mosquitoes, and when they are "bad," one hears little else.

Naturally enough these communities were among the first to become interested in the matter of mosquito control and South Orange, under the direction of Mr. Spencer Miller, was the first community to do systematic work. A history of this work as given by Mr. S. E. Allen, a member of the South Orange Board of Health, will be found on a subsequent page.

The work was begun while the idea was dominant that mosquitoes did not in any case travel far from their place of birth and that a community could protect itself no matter what its neighbors might do or fail to do.

There is no question that conditions have been vastly improved at South Orange, to the point almost of practically wiping out local breeding places. Nevertheless the town is not free from mosquitoes and sometimes there are a great many of them.

Among the earliest points investigated by me were: *first*, what species of mosquitoes do really occur in numbers in the towns along the Orange Mountains and, *second*, what species breed in the mountains or in the localities themselves. The result was interesting enough, for it determined that, while there were plenty of mosquitoes bred in the woods on the mountains and along their base, the species that were active in the streets and on porches were not these locals, but the salt marsh forms.

The full range of towns was collected over, not once but many times, in every month of the summer and for three years. In addition specimens were sent me from time to time during each summer and, from the earliest appearance of the insects until midsummer at least, *cantator* and *sollicitans* were almost exclusively present. After that period *pipiens* began to be represented, especially indoors, and *sylvestris* joined the salt marsh species as an outdoor pest.

On the mountain sides and tops where they are covered with woodland there are many holes and sink-like depressions which hold melted snow and spring rains long enough to bring large

broods of *Culex canadensis, trivittatus* and a number of other species to maturity. No *pipiens* are found in these pools; but *Anopheles* does occur there in some numbers at times. In July and August most of these pools dry up, except where formed by springs which have no other outlet. In the fall, rains usually refill the pools and breeding goes on until late, *sylvestris* now becoming prominent and replacing *canadensis* as the most numerous species. At this time *Anopheles* also becomes a greater factor and specimens are not at all rare.

Except for *Anopheles* and *Culex sylvestris* the mosquito output from these woodland pools remains very much at home and the species are rarely or not at all found in the towns. As a large portion of this territory is in the hands of the Essex County Park Commission and is reserved as a public park, it will be in order as a part of the general improvements, to do away with as many of these pools as possible for the comfort of the many visitors already attracted by the beauty of the place.

At and near Vailsburgh is a swampy meadow area which breeds *sylvestris* in great quantities and supplies the neighborhood for a considerable distance round about. In the towns themselves there are the usual sunken lots, bits of swamp land, cess-pools, water barrels, etc., in which *pipiens* delights, and of such places many have been improved out of existence.

From a practical standpoint the mountain breeding areas cause little trouble in the towns along the base. *Culex sylvestris* is the only species of local extraction that comes from any distance and all low meadow pools and marshy bits are likely to supply this. The only large area is that already mentioned at Vailsburgh. *Culex pipiens* of course breeds wherever an opportunity occurs and is the only really troublesome form indoors. The great majority, say seventy-five per cent. of all the mosquitoes infesting the towns, are *cantator* and *sollicitans* or the salt marsh migrants.

The following comes from Dr. T. N. Gray, the medical officer of the Board of Health at East Orange, under date September 30th, 1904:

"In East Orange, during the past spring and summer, we have devoted the greater part of our energy to oiling. Our scheme for the permanent wiping out of the mosquito is to fill in the low places. We do this because East Orange has no open water courses. As filling in with dirt is a very costly work we have not pushed it so far, preferring to wait until furnaces come in use, and those owning the localities to be filled in can have the benefit of the ashes and cinders collected by the public scavenger, and which will cost nothing, the only expense being the few inches of dirt which the ordinance requires as a top dressing over ashes. We have found no trouble with the operation of the new law; indeed, it has saved us trouble, as in case the owner proves obstinate we do not have to go into court to prove a

nuisance, the law so distinctly saying that the presence of mosquito larvæ in water constitutes a nuisance. Constant oiling has proved effective, and I have found very few local mosquitoes this summer, the bulk of those observed being visitors from the marshes. I have no doubt that when the Newark Board of Works relieves the one spot on the Newark meadows, which is breeding ground not amenable to ditching, and Elizabeth can be imbued with enough life and go to get to work, that Essex county will be practically free from mosquitoes, providing local boards of health do their part."

(Signed) T. N. GRAY.

The following report on the South Orange work is submitted by Mr. S. E. Allen:

"The anti-mosquito work in South Orange began in the spring of 1901. The field presented many difficulties. The town had then no sewerage system. There were 1,700 cesspools and settling basins, many of which were found to contain larvæ. In common with other suburban towns, streets had been laid out in many places in such a manner as to obstruct the natural drainage and create swampy areas. The area treated is two miles long by one and three-quarters wide, and scattered throughout are tracts of rough woodland concealing pools of water, and by their shade preventing rapid evaporation. The ground is high, but the soil is largely clay and not easily drained. The close proximity of large areas of swampy land on the top of the Orange Mountains on the one side, and the threat of invasion by mosquitoes from the Newark Meadows following a few days of east wind, render it difficult to disassociate the homebred from the imported mosquitoes, and so estimate the results.

"It was decided that if the local broods were eliminated and breeding places abolished, the importation from outside would cause only temporary discomfort and would rapidly disappear soon after their arrival.

"During the first year a large amount of oil (about sixty barrels in all) was used: for a part of the season crude petroleum, and at the end a contract was made with the manufacturer of a chemical oil. The results attained were encouraging. The amount expended was about $1000. It was recognized, however, that oil was but a temporary and an expensive expedient—that drainage was the only permanent cure.

"Accordingly, in the spring of 1902 a systematic scheme to promote drainage was commenced. The town was divided into four districts, with a committee over each, whose business it was to raise money and expend it to the best advantage, each on its own district. The owners of property containing stagnant water were requested to drain and fill in, which many of them did. When owners could not be reached, the funds raised by subscription were applied. Sometimes the owners paid part, and the balance

was made up from the general fund. During the season the oiling was continued. The results were a most pronounced success. About $1200 was raised in 1902, which was expended about equally in oiling and in ditching.

"By the spring of 1903 the public authorities had begun to recognize the progress that had been made. The Board of Health assumed the work of distributing the oil, and the committee was enabled to turn its attention entirely to drainage. The drainage consisted of open ditches, and experience showed that in order to remain effective the ditches must be cleaned out in the spring, and that in mid-summer the weeds must be cut away, in order that the sun could dry the ditches and the men with the oil sprayer be able to reach those which might contain water. The subscriptions for 1903 continued to increase over preceding years, and a large amount of drainage was effected. About $1400 was expended in this way. Owing to the continuous rains of the early summer of 1903, the results were not so good as in the preceding years. That season will be remembered for the enormous crop of mosquitoes which it produced throughout the Middle and Eastern States. In many places where they had never been known before they became a veritable plague. Toward the end of the season, when the rains ceased and the water was carried off by the ditches, the mosquitoes disappeared from South Orange more rapidly than in other places which had not protected themselves.

"During the season of 1904 work has progressed upon similar lines. The Board of Health has attended to the oiling, and the committee has looked after the drainage and cutting of the weeds. About $1000 has been so expended.

"The results of the three years' work has transformed large areas of what had been unsightly swamp land, well nigh impassable through the myriads of mosquitoes which it bred, into dry fields, pleasant to look upon or walk through, and mosquito proof. Much of the land so treated is now under cultivation—some of it as a part of a golf course.

"During the session of 1903-04 the Legislature of New Jersey passed what is known as the 'Duffield Act,' enabling the Board of Health to condemn as nuisances lands where mosquito larvæ are found. This act is destined to be of great assistance in compelling recalcitrant land owners to do their duty by the community. An instructive application of the law was made in South Orange. A stream extending for a distance of 2,000 feet through the lands of several different owners had become clogged with the roots of trees and filled in through many years' neglect,

so that it had no adequate fall and formed a series of small stagnant pools where mosquito larvæ were found in abundance. In pursuance of the Duffield Act, the owners of the land were notified to abolish the nuisance. The village engineer ran levels and a grade was established which would insure a regular flow, and the owners were notified to open the portion of the stream within their land down to the grade. The board offered to do this work under its own supervision for those of the owners who desired it, and as several of them are non-residents, the offer was generally accepted and the work is now going forward. The expense will be about $600, and it will transform a damp and swampy woodland into attractive building lots. It will redeem about twenty acres of mosquito breeding area.

"A statement of the methods and cost of the work may be of value. A regular gang of workmen was organized under an intelligent foreman and placed in the service of the local committees, who soon became skillful at the work. Where a hillock was found conveniently located, it was cut down and the earth used to fill in neighboring holes. The ditches are at distances varying with the character of the ground. They have a large V cross-section and do not easily fill up. When they cannot be connected with a running stream, they are led to a common center at the lowest point, where the water gathers, and can readily be oiled. One tract of four acres was drained for $40; another containing three and one-half acres cost $85. The average is about $25 per acre. The methods of oiling have also been much improved and cheapened. A sprayer working by pneumatic pressure, such as is used for trees of a size to be readily carried by one man, has been found to be very effective and economical in operation. The elimination of 17,000 cesspools by the introduction of sewerage and the removal of swamps by drainage will greatly reduce the necessity for oil. It will probably, however, be several years before all breeding places are entirely abolished in low lands for which there is no outlet, so that oiling will still be required, though to a much smaller extent than heretofore. (Signed) S. E. ALLEN."

This report is instructive and, to one acquainted with the facts, as eloquent for what it does not say as for the progress recorded. There is no word of the opposition, active and passive, that was encountered; no word of the infinite patience required to secure subscriptions; no word of the ridicule and abuse when swarms of mosquitoes appeared from no one knew where, before the influence of the salt marsh was understood and appreciated.

It is noteworthy that Mr. Allen joins Dr. Gray and Mr. Winship in his estimate of the value of the Duffield amendment to the health laws, and I may say here that wherever any efforts have been made by local boards, the amendment has cleared the way and simplified matters for them.

Nor does Mr. Allen say aught concerning the educational campaign of the society. This is one of the most important features of their work and the unique circular prepared under the direction of Mr. Spencer Miller is worthy of insertion here.

INFORMATION ABOUT MOSQUITO

ISSUED BY THE DRAINAGE COMMITTEE OF THE

VILLAGE IMPROVEMENT SOCIETY

OF SOUTH ORANGE, N. J.

NOTE. The above illustration is a correct representation of the breeding of the commonest of our domestic mosquitoes, (*Culex pipiens*). The story of one puddle is the story of a million puddles. The sun may usually be depended upon to dry up the great majority of such puddles before 10 days elapse.